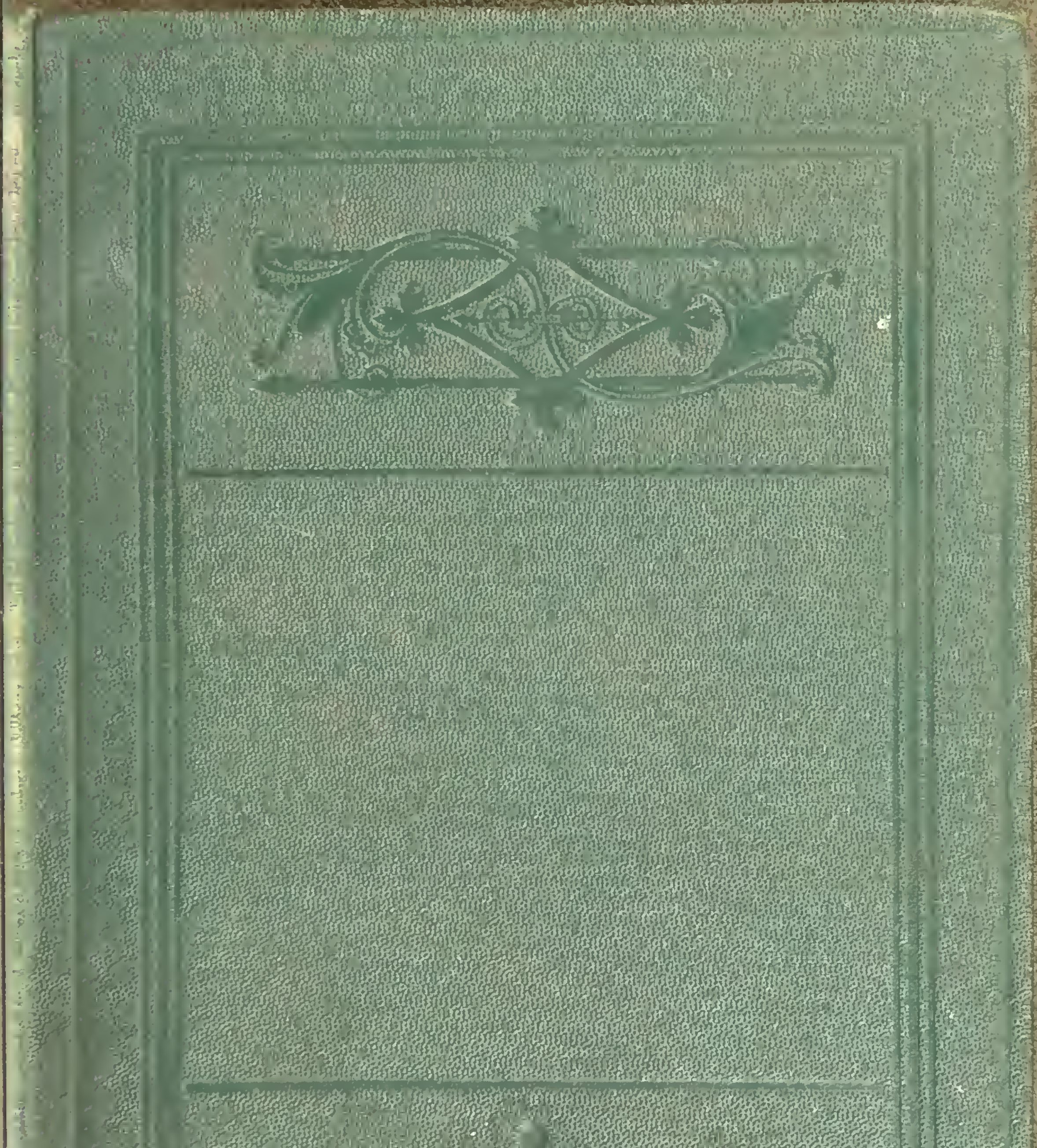

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A
MANUAL OF BOTANY

VOL. II

CLASSIFICATION AND PHYSIOLOGY

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A
MANUAL OF BOTANY

BY

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PROFESSOR OF BOTANY TO THE PHARMACEUTICAL SOCIETY
OF GREAT BRITAIN

VOL. II

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PREFACE

TO

THE SECOND EDITION

In preparing this edition for the press I have entirely rewritten the somewhat considerable section that treats of the Spermaphyta, or flowering plants, and have endeavoured to make it at once more readable and more useful to the student of the British Flora. The Natural Orders which are represented in the United Kingdom have been treated more fully than before, and many points of difficulty in the morphology of their flowers have been discussed.

J. REYNOLDS GREEN.

Cambridge : *December* 1901.

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ERRATA

Page 206, line 27, *for* Leparidinæ *read* Liparidinæ.
Page 331, line 3, *for* Paniceæ *read* Puniceæ.

MANUAL OF BOTANY.

BOOK III.

SYSTEMATIC BOTANY, OR THE CLASSIFICATION OF PLANTS.

CHAPTER I.

GENERAL PRINCIPLES OF CLASSIFICATION.

SECTION 1.—SPECIES, GENERA, ORDERS, AND CLASSES.

OUR attention has been hitherto directed to the examination of the structure and shapes of the various organs and parts of plants. In doing so, we cannot but have noticed the almost infinite varieties of forms which have thus been presented to us, and also at the same time observed that, notwithstanding such variations, there are some striking resemblances in the structure of the members of certain plants, by which a close relationship is thus clearly indicated between them. It is the object of Systematic Botany to take notice of such relationships, and thus to group together plants which are allied in their forms and structure, while we distinguish between those that are unlike. In this way we are able to take a comprehensive view of the whole Vegetable Kingdom. In its extended sense, Systematic Botany has for its object the naming, describing, and arranging of plants in such a manner that we may get an insight into their affinities and general properties.

Before we proceed to describe the systems that have been devised at various times for their arrangement, it will be necessary, however, to define the principal terms which are in common use in such systems.

1. SPECIES.—By the term species we understand a collection of individuals which resemble each other as closely as they resemble their parents and their offspring. Thus, if we walk into a field of Beans, Peas, or Clover, we observe thousands of individuals, which, although differing to a certain extent in size, and in some other unimportant characters, we at once associate together under a common name. Species are, however, under special conditions, liable to variations, and we have then formed what are termed *varieties* and *races*.

a. *Varieties or Sub-species.*—If a species be propagated it will generally produce a plant resembling its parent in all its important parts. But this will only happen when the new individual has been exposed to the same influences of soil, heat, light, moisture, and other conditions, as its parent; and hence we find that variations in such particulars will lead to certain peculiarities in form, colour, size, and other minor characters, in the young plants. In this manner we have produced what are termed *varieties*.

These varieties are not permanent; for successive generations which may be produced from them will have a tendency to revert to the original species from which such varieties have been obtained. Thus, if we sow the seeds of a number of different varieties of Apples, some of the fruits subsequently produced by the new generation of Apple trees will, instead of resembling that of their parents, have a tendency to revert to that of the common Crab, from which species all such varieties have been originally derived. A variety differs essentially from a species in the fact that it cannot be propagated without tending to revert to the type from which it sprang.

b. *Races.*—Besides the varieties just alluded to, there are others, which are called *permanent varieties* or *races*, because their peculiarities can be transmitted by seed. Familiar examples of such races are afforded by our Cereal grains, as Wheat, Oats, and Barley; and also by our culinary vegetables, as Peas, Lettuces, Radishes, Cabbages, Cauliflowers, and Broccoli. How such races of plants have originated, it is impossible to say with any certainty. At the outset they probably arose in an accidental manner, for it is found that plants under cultivation are liable to produce certain variations or abnormal deviations from their specific type, or to *sport*, as it is termed. By further cultivation under the care of the gardener, such variations are after a time rendered permanent, and can be propagated by seed. These so-called permanent varieties, however, if left to themselves, or if sown in poor soil, will soon lose their peculiarities, and either perish, or return to their original specific type; it will be seen, therefore, that races present well-marked characters by which they are distinguished from true species.

Another cause which leads to constant variations from the specific type is *hybridisation.* The varieties thus formed, which are called *hybrids* and *cross-breeds*, are, however, rarely constant for long—although, in some instances, such is the case for a few generations—but they gradually revert to one or the other parent stock.

In practice it is important that we should distinguish varieties from true species, for nothing is so calculated to lead to confusion as the raising of mere varieties to the rank of species. No individuals should be considered as constituting a species unless they exhibit important and permanent distinctive characters in a wild state. Great uncertainty still prevails in our systematic works as to what is a species and what is a variety; and hence we find different authors, who have written on British and other plants, estimate very differently the number of species contained in such genera as *Rosa*, *Rubus*, *Saxifraga*, *Hieracium*, *Salix*, *Smilax*, and others.

2. GENERA.—The most superficial observer of plants will have noticed that certain species are more nearly allied to each other than to other species. Thus, the different kinds of Roses, Brambles, Heaths, Willows, may be cited as familiar examples of such assemblages of species; for although the plants comprehended under these names present certain well-marked distinctive characters, yet there are at the same time also striking resemblances between them. Such assemblages of species are called *genera.* A *genus*, therefore, is a collection of species which resemble each other in general structure and appearance more than they resemble any other species. Thus, the various kinds of Brambles constitute one genus, the Roses another, the Willows, Heaths, Clovers, and Oaks form also, in like manner, as many different genera. The characters of a genus are taken from the organs of reproduction, while those of a species are derived more often from the vegetative parts of the plant; hence a genus is defined as a collection of species which resemble each other in the structure and general characters of their organs of reproduction. It is not necessary, however, that a genus should contain a number of species, for, if a single species presents

peculiarities of a marked kind, it may of itself constitute a genus.

It frequently happens that two or more species of a genus have a more striking resemblance to each other in certain important characters than to other species of the same genus, in which case they are grouped together into what is termed a *sub-genus*, and further subdivisions of more nearly allied species, such as *sections*, *sub-sections*, &c., may be made.

3. ORDERS OR NATURAL ORDERS.—If we regard collections of genera from the same point of view as we have just done those of species—that is, as to their close resemblances—we shall find that some of them also resemble each other more than they do other genera. Thus, Mustards, Turnips, Radishes, and Cabbages have a strong common resemblance, while they are unlike Strawberries and Brambles, even less like Hazels, Oaks, and Beeches, and still more unlike Larches, Pines, Firs, and Cedars. Proceeding in this way throughout the Vegetable Kingdom, we collect together allied genera, and form them into groups of a higher order called *Orders* or *Natural Orders*, laying stress particularly on the structure of the flowers, fruit, and seeds; hence, while genera are collections of related species, orders are collections of allied genera. Thus, Turnips, Radishes, and Cabbages, all belong to different genera, but they agree in the general structure of their flowers and fruit, and are hence included in the order *Cruciferæ*.

We find also that certain genera of an order, like certain species of a genus, have a more striking resemblance to each other than to other genera of the same order; such are grouped together into what are called *Sub-orders*. Thus the Chicory, Dandelion, Sow-thistle, Lettuce, Thistle, Burdock, and Chamomile, all belong to the same order, but there is a greater resemblance in the Chicory, Dandelion, Sow-thistle, and Lettuce to each other than to the Thistle and Burdock. Hence, while all the above genera belong to the order *Compositæ*, they are at the same time placed in two different sub-orders. One sub-order, called the *Liguliforæ*, includes the Chicory, Dandelion, Sow-thistle, and Lettuce; and another sub-order, the *Tubuliforæ*, that of the Thistle, Burdock, and Chamomile. In like manner, while we find the Plum, Strawberry, Raspberry, Rose, and Apple, all belonging to the same order *Rosaceæ*, some of them have closer resemblances in one direction than another. Thus, the Plum has a drupaceous fruit, and is therefore placed in a distinct sub-order, which is called *Drupaceæ*; the Strawberry, Raspberry, and Rose are much more like each other than they are like the Plum or Apple, and they are put in a sub-order called *Roseæ*; while the Apple, from the character of its fruit, is placed in a sub-order termed *Pomeæ*.

It is also found convenient to subdivide sub-orders into *Tribes*, *Sub-tribes*, &c., by collecting together into groups certain very nearly allied genera, but it is not necessary for us to illustrate such divisions further, as the principles upon which they depend have been now sufficiently treated of.

4. Classes.—By a class we understand a group of orders possessing some very important structural characters in common. Thus we have the classes Monocotyledones and Dicotyledones, which possess certain distinctive characters in their respective embryos, &c.

The Classes are also divided into *Sub-classes*, *Series*, *Cohorts* or *Alliances*, and other divisions, in the same manner as the orders, genera, and species are subdivided; but as the names of such divisions vary in different systems, and are all more or less artificial, it is not necessary for us at present to dwell upon them further. The classes themselves, in different systems, are also generally arranged in more comprehensive groups, which have been variously named *Sub-kingdoms*, *Groups*, *Divisions*, *Regions*, *Sub-divisions*, &c. But as these are also of different extent and variously defined by botanists, we must refer to the several systems for particulars respecting them.

The following table will include all the more important groups we have alluded to; those in more general use being indicated by capital letters.

1. SUB-KINGDOMS OR DIVISIONS.
    - Sub-divisions.
        2. CLASSES.
            - Sub-classes.
                - Series.
                    - Cohorts or Alliances.
                        3. ORDERS.
                            - Sub-orders.
                                - Tribes.
                                    - Sub-tribes.
                                        4. GENERA.
                                            - Sub-genera.
                                                - Sections.
                                                    5. SPECIES.
                                                        - Varieties.
                                                            - Races.

SECTION 2.—CHARACTERS, NOMENCLATURE, ABBREVIATIONS, AND SYMBOLS.

DESCRIPTIVE BOTANY is the art of describing plants in technical language, so that they may be readily recognised when met with by those to whom they were previously unknown, who possess a knowledge of the technical names of the different parts and organs of plants and of their various modifications. This subject is too extensive to be treated of here; reference must be made to special treatises for this purpose; but it is necessary for us to refer briefly to the Characters of plants and the Nomenclature, Abbreviations, and Symbols in use.

1. CHARACTERS.—By the term 'character' we mean the points by which any particular *variety*, *species*, *sub-genus*, *genus*, *sub-tribe*, *tribe*, *sub-order*, *order*, *sub-class*, or *class*, &c., is distinguished from another. We recognise two kinds of characters, which are called respectively *essential* and *natural*. An essential character comprises those points only by which any division of plants may be distinguished from others of the same nature; such may be also called *diagnostic* characters. A natural character, on the other hand, involves a complete description of a given species, genus, order, class, &c., including an account of every organ from the root upwards, through the stem, leaves, flowers, fruit, and seed. Such descriptions are necessarily of great length, and are not required for general diagnosis, although they are of great value when a complete history of a plant or group is required. The characters which distinguish a species are called *specific*, and are taken generally from all the organs and parts of the plant; they relate chiefly to their *form*, *shape*, *surface*, *division*, *colour*, *dimension*, and *duration*; or, in other words, to points of a superficial nature, omitting all reference to their internal structure. The characters of a genus are called *generic*, and are largely based upon the organs of reproduction. The characters of an order are termed *ordinal*, and are derived from the general structure of the plants in such groups, more especially of the organs of reproduction; while the characters of a class, &c., as already mentioned, are derived from certain fundamental structural peculiarities which the plants of such divisions exhibit.

2. NOMENCLATURE.—It is the object of nomenclature to lay down rules for naming the various kinds of plants and the different groups into which they are arranged in our systems of classification; in the same manner as it is the object of

terminology to find names for the different organs of plants, and the modifications which those organs present.

a. *Species.*—The names of the species are variously derived. Thus the species of the genus *Viola*, as shown by Gray in the following paragraphs, exhibit the origin of many such names. ‘Specific names sometimes distinguish the country which a plant inhabits : for example, *Viola canadensis*, the Canadian Violet; or the station where it naturally grows, as *Viola palustris*, which is found in swamps, and *Viola arvensis*, in fields ; or they express some obvious character of the species, as *Viola rostrata*, where the corolla bears a remarkably long spur, *Viola tricolor*, which has tri-coloured flowers, *Viola rotundifolia*, with rounded leaves, *Viola lanceolata*, with lanceolate leaves, *Viola pedata*, with pedately-parted leaves, *Viola primulæfolia*, where the leaves are compared to those of a Primrose, *Viola asarifolia*, where they are likened to those of *Asarum*, *Viola pubescens*, which is hairy throughout, &c. Frequently the species bears the name of its discoverer or describer, as *Viola Muhlenbergii*, *Viola Nuttallii*, &c.

Specific names are written after the generic, as indicated above in the different species of the genus *Viola*, and these together constitute the proper appellation of a plant, in the same way as the surnames and christian names designate the members of a family. The specific names should also in all cases be adjectives or substantives used adjectively; the former should agree in gender and case with the name of the genus. When a species is named after its discoverer or describer, it is usually placed in the genitive case, as *Viola Muhlenbergii* and *V. Nuttallii*; but when such names are merely given in honour of botanists who have had nothing to do with their discovery or description, the specific names are generally put in the adjectival form, as *Carex Hookeriana*, *Veronica Lindleyana* : such a rule is, however, frequently departed from. Sometimes the specific name is a noun, in which case it does not necessarily agree with the genus in gender; such specific names are often old generic ones, as *Dictamnus Fraxinella*, *Rhus Cotinus*, *Lythrum Salicaria*, *Rhus Coriaria*, *Dianthus Armeria*, *Rhamnus Frangula.* In such cases the specific name should begin with a capital letter; a similar rule should also be adopted when it is derived from a person; but in all other instances it is better that the specific name should begin with a small letter. The specific name was called by Linnæus the *trivial* name; thus, in the particular kind of Violet called *Viola* *palustris*, *Viola* is the generic, and *palustris* the specific or trivial name.

b. *Genera.*—The names of the genera are substantives, in accordance with the rule laid down by Linnæus as follows:—Every species shall have a particular name, compounded of a substantive and an adjective, whereof the former indicates the genus, and the latter the species. This has already been referred to under the head of Species. The names of the genera are derived in various ways: either from the name of some eminent botanist, as *Linnæa* after Linnæus, *Smithia* after Smith, *Hookeria* after Hooker, *Jussiæ* after Jussieu, *Tournefortia* after Tournefort, *Lindleyana* after Lindley; or from some peculiarity of structure or habit of the plants comprised in them, or from various other circumstances. Thus, *Crassula* is the name of a genus comprising plants with succulent or thickened leaves; *Sagittaria* takes its name from its arrow-shaped leaves; *Arenaria*, from its growing in sandy places; *Lithospermum*, from its fruits (which were formerly regarded as seeds) having a stony hardness; *Campanula*, from its corolla being in the form of a bell; *Lactuca*, from its milky juice; and so on. Others, again, have derived their generic names from supposed medicinal properties, such as *Scrophularia*, from its former use in scrofula; *Pulmonaria*, from its employment in pulmonary disease, &c.

c. *Orders.* The names of the orders in the Artificial System of Linnæus are chiefly derived from the various characters of the gynœcium and fruit. Those of Natural Systems are usually taken from some well-known genus which is included in any particular order, and which may be regarded as the type of that order. The genus *Ranunculus* gives the name *Ranunculaceæ* to the order to which it belongs; the genera *Papaver*, *Malva*, *Hypericum*, *Geranium*, *Rosa*, *Lilium*, *Orchis* and *Iris*, in like manner, give names respectively to the orders, *Papaveraceæ*, *Malvaceæ*, *Hypericaceæ*, *Geraniaceæ*, *Rosaceæ*, *Liliaceæ*, *Orchidaceæ*, and *Iridaceæ*. At other times the names of the orders are derived from some characteristic feature which the plants included in them present. The order *Cruciferæ* is so named because its plants have cruciate corollas; the order *Leguminosæ* because the fruit of its members is, with few exceptions, a legume; the *Umbelliferæ* are umbel-bearing plants; the *Labiatæ* have a labiate corolla; the *Coniferæ* are cone-bearing plants; and so on.

d. *Classes.*—The names of the classes are derived from some important and permanent characters which the plants comprised in them possess, relating either to their structure or mode of development. Such names vary, however, according to the views of different systematic botanists. Examples of those which have been more commonly used in this country are *Monocotyledones* and *Dicotyledones*—terms which are derived from the structure and characters of the embryos in those respective classes. These names are used especially in Natural Systems of Classification; while those of classes in the Artificial System of Linnæus are derived chiefly from the peculiarities presented by the andrœcium.

c. *Sub-kingdoms*, *Divisions*, *&c.*—The names of these are generally derived from some well-marked peculiarity of typical forms; thus we have the *Bryophyta* or Moss-like plants, the *Pteridophyta* or Fern-like plants, the *Spermaphyta* or plants which produce seeds, sometimes called *Phanerogamia* because their sporophylls are usually collected into evident flowers. The other sub-divisions are variously named according to the views of different botanists.

3. Abbreviations and Symbols.—It is usual in botanical works to use certain abbreviations and symbols. Only a few of the more important need be mentioned here.

The names of authors. when of more than one syllable, are commonly abbreviated by writing the first letter or syllable, &c., as follows:—

L. or *Linn.* means Linnæus; *Juss.* is the abbreviation for Jussieu; *DC.* or *De Cand.* for De Candolle; *Br.* for Brown; *Lindl.* for Lindley; *Rich.* for Richard; *Willd.* for Willdenow; *Hook.* for Hooker; *With.* for Withering; *Endl.* for Endlicher; *Bab.* for Babington; *Berk.* for Berkley, &c., &c.

It is common to put such abridged names after that of the genus or species which has been described by these authors respectively. Thus *Eriocaulon*, *L.* indicates that the genus *Eriocaulon* was first described by Linnæus; *Miltonia*, *Lindl.* is the genus *Miltonia* as defined by Lindley; *Nuphar pumila*, *DC.* is the species of *Nuphar* defined by De Candolle, &c., &c.

Other abbreviations in common use are *Rad.* for root; *Caul.* for stem; *Fl.* for flower; *Cal.* for calyx; *Cor.* for corolla; *Per.* for perianth; *Fr.* for fruit; *Ord.* for order; *Gen.* for genus; *Sp.* or *Spec.* for species; *Var.* for variety; *Hab.* for habitat; *Herb.* for herbarium, &c.

CHAPTER II.

SYSTEMS OF CLASSIFICATION.

We have already stated that Systematic Botany has for its object the naming, describing, and arranging of plants in such a manner that we may readily ascertain their names, and at the same time get an insight into their affinities and general properties. Every system that has been devised for the arrangement of plants does not, however, comprise all the above points; for, while some systems are of value simply for affording us a ready means of ascertaining their names, others not only do this, but at the same time give us a knowledge of their affinities and properties. Hence we divide the different systems of Classification under two heads; namely, Artificial and Natural—the former only necessarily enable us to ascertain readily the name of a particular plant; while the latter, if perfect, put before us all the points which come within the scope of Systematic Botany. The great aim of the botanist, therefore, should be the development of a true Natural System; but in past times, Artificial Systems, more particularly that of Linnæus, have been of great value. Linnæus himself never devised his system with any expectation or desire of its serving more than a temporary purpose, or being an introduction to the Natural System, when the materials for the construction of the latter should have been obtained.

In both artificial and natural systems, the lower divisions—namely, the genera and species—are the same, the difference between the systems consisting in the manner in which these divisions are grouped into orders, classes, and other higher ranks. In the Linnæan and other artificial systems, one, or, at most, a few characters are arbitrarily selected, and all the plants in the Vegetable Kingdom are distributed under classes and orders according to the correspondence or difference of the several genera in such respects, no regard being had to any other characters. The plants in the classes and orders of an artificial system have, therefore, no necessary agreement with each other except in the characters selected for convenience as the types of those divisions respectively. Hence such a system may be compared to a dictionary, in which words are arranged, for convenience of reference, in an alphabetical order, adjacent words having no necessary agreement with each other, except in commencing with the same letter. In the Natural System, on the contrary, all the characters of the genera are taken into consideration, and those are grouped together into orders which correspond in the greatest number of important characters; and the orders are again united, upon the same principles, into groups of a higher order, namely, the classes and other divisions. It must be evident, therefore, that all the knowledge we necessarily gain by an artificial system is the name of an unknown plant, while on the other hand, by the natural system, we learn not only the name, but also its relations to the plants by which it is surrounded, and hence get a clue to its structure, properties, and history. Thus, supposing we find a plant, and wish to ascertain its name, if we turn to the Linnæan System and find that such a plant is the *Menyanthes trifoliata*, this name is the whole amount of the knowledge we have gained; but by turning to the Natural System instead, and finding that our plant belongs to the order *Gentianaceæ*, we ascertain at once from its affinities that it probably has the tonic and other properties which are possessed by the plants generally of that order, and, at the same time, we also learn that it accords in its structure with the same plants. It is quite true that all the orders, as at present constituted, are by no means so natural as that of the Gentianaceæ, but this arises from the present imperfection of our systems, and can only be remedied as our knowledge of plants extends; a system, devised as perfectly as possible one day, may be deficient the next, in consequence of the discovery of new plants which may compel us to alter our views, for at present we are only imperfectly acquainted with the floras of many regions of the globe, and those of others are almost entirely unknown. Sufficient, however, is now known of plants to enable us to establish certain great divisions according to a natural method, which subsequent discoveries are not likely to affect to any important extent. The present imperfections of the Natural System are, therefore, comparatively unimportant, and will no doubt disappear as our knowledge of the flora of the globe becomes extended.

Having now described the general characters upon which

TABULAR VIEW OF THE LINNÆAN ARTIFICIAL SYSTEM.

					Classes.	Orders.
Stamens and pistil in the same flower.	Stamens separate from the pistil.	Stamens not connected with each other.	Stamens of equal length, or at all events neither didynamous nor tetradynamous.	1 Stamen . . .	1. MONANDRIA .	1. Monogynia, 1 free style or stigma.
				2 Stamens . . .	2. DIANDRIA .	2. Digynia, 2 free styles or stigmas.
				3 ,, ...	3. TRIANDRIA .	3. Trigynia, 3 ,, ,,
				4 ,, ...	4. TETRANDRIA .	4. Tetragynia, 4 ,, ,,
				5 ,, ...	5. PENTANDRIA .	5. Pentagynia, 5 ,, ,,
				6 ,, ...	6. HEXANDRIA .	6. Hexagynia, 6 ,, ,,
				7 ,, ...	7. HEPTANDRIA .	7. Heptagynia, 7 ,, ,,
				8 ,, ...	8. OCTANDRIA .	8. Octagynia, 8 ,, ,,
				9 ,, ...	9. ENNEANDRIA .	9. Enneagynia, 9 ,, ,,
				10 ,, ...	10. DECANDRIA. .	10. Decagynia, 10 ,, ,,
				12 to 19.. . . .	11. DODECANDRIA .	11. Dodecagynia, 12 to 19 ,, ,,
				20 or more, perigynous	12. ICOSANDRIA .	12. Polygynia, 20 or more ,, ,,
				20 or more, hypogynous	13. POLYANDRIA .	
			Of unequal length.	Two long and two short stamens.	14. DIDYNAMIA .	1. Gymnospermia, Fruit achænia, with one seed. 2. Angiospermia, Fruit capsular, with many seeds.
				Four long and two short stamens.	15. TETRADYNAMIA .	1. Siliculosa, Fruit a Silicula. 2. Siliquosa, Fruit a Siliqua.
		Connected with each other.		By their filaments in one bundle.	16. MONADELPHIA .	1. Triandria, 3 stamens.
				By their filaments in two bundles.	17. DIADELPHIA .	2. Pentandria, 5 stamens.
				By their filaments in more than two bundles.	18. POLYADELPHIA .	3. Hexandria, 6 stamens. &c., &c., as in first 13 classes.
						1. Polygamia æqualis. Florets in capitula, and all perfect. 2. Polygamia superflua. Florets in capitula: florets of the disc hermaphrodite, of the ray pistillate.

			Class	Orders
Plants having	Stamens and pistil evident.	By their anthers.	19. SYNGENESIA	3. Polygamia frustranea. Florets in capitula; those of the disc hermaphrodite, and those of the ray neuter. 4. Polygamia necessaria. Florets in capitula; those of the disc staminate, and those of the ray pistillate. 5. Polygamia segregata. Florets in capitula: each with a separate involucre.
		Stamen or stamens adherent to the pistil	20. GYNANDRIA	1. Monandria, 1 stamen. 2. Diandria, 2 stamens; and so on according to the number of stamens, as in the first 13 classes.
	In separate flowers	On the same plant	21. MONŒCIA	1. Monandria, 1 stamen. 2. Diandria, 2 stamens. 3. Hexandria, 6 stamens. 4. Polyandria, numerous stamens; and so on, as in the first 13 classes. 5. Monadelphia, stamens united into one bundle by their filaments. 6. Polyadelphia, stamens united into several bundles by their filaments.
		On separate plants	22. DIŒCIA	
		Stamens and pistil separate in some flowers, and united in others, either on the same or on two or three different plants.	23. POLYGAMIA.	1. Monœcia, with staminate, pistillate, and hermaphrodite flowers on the same plant. 2. Diœcia, with hermaphrodite flowers on one plant, and staminate and pistillate flowers on another plant of the same species. 3. Triœcia, where one plant bears hermaphrodite, another staminate, and a third pistillate flowers.
Plants with organs of reproduction concealed or inconspicuous			24. CRYPTOGAMIA	Ferns, Mosses, Algæ, Fungi.

the artificial and natural systems depend, and the particular merits and disadvantages of the two kinds of system respectively, we may proceed in the next place to describe the mode of construction of such systems, commencing with those of an artificial nature, which, however, will be only treated of very briefly.

SECTION 1.—ARTIFICIAL SYSTEMS OF CLASSIFICATION.

THE first artificial system of any importance, of which we have any particular record, is that of Cæsalpinus, which was promulgated in 1583. Only 1,520 plants were then known; and these were distributed into fifteen classes, the characters of which were chiefly derived from the fruit. The next systematic arrangement of an artificial character was that of Morison, about the year 1670. He divided plants into eighteen classes, which were constructed according to the nature of the flower and fruit, and the external appearance of the plants. The systems of Hermann and others were also constructed upon somewhat similar principles, while that of Camellus was framed from the characters presented by the valves of the pericarp, and their number. In the system of Rivinus, which was promulgated in the year 1690, plants were divided into eighteen classes; these were founded entirely upon the corolla—its regularity or irregularity, and the number of its parts being taken into consideration. The system of Christian Knaut was but a slight alteration of that of Rivinus. That of Tournefort, which was promulgated about the year 1695, was for a considerable time the favourite system of all botanists. About 8,000 species of plants were then known, which were distributed by Tournefort into twenty-two classes. He first arranged plants in two divisions, one of which comprised *herbs* and *under-shrubs*, and the other *trees* and *shrubs*: and each of these divisions was then divided into *classes*, which were chiefly characterised according to the form of the corolla. Many other systems were devised which were simply alterations of the foregoing, as that of Pontedera. Magnolius, however, framed a system entirely on the calyx; while Gleditsch attempted one in which the classes were founded on the position of the stamens. All the above systems were, without doubt, useful in their day, and paved the way for the more comprehensive one of Linnæus.

LINNÆAN SYSTEM.—This celebrated system was first promulgated by Linnæus in his 'Systema Naturæ,' published in the year 1735; and although it was somewhat altered by subsequent botanists, the Linnæan System, in all its essential characters, was that devised by Linnæus himself; and although now superseded by natural systems, it will be advisable for us to give a general sketch of its principal characteristics.

The classes and orders in the Linnæan System are taken exclusively from the sporophylls ; as these were considered to be the sexual organs of the plant, this artificial scheme is commonly termed the Sexual System.

The table (pp. 12 and 13) of the Classes and Orders of the Linnæan System will show at a glance their distinctive characteristics.

SECTION 2.—NATURAL SYSTEMS OF CLASSIFICATION.

One of the earliest attempts at arranging plants according to their natural affinities was made by our celebrated countryman, John Ray, in the year 1682 ; and imperfect as any scheme must necessarily have been at that day, when the number of plants known was very limited, still his arrangement was of considerable value. He was the first to recognise the importance of the structure of the embryo. He divided plants into herbs and trees. Of the former he made two divisions, the first comprising plants without flowers, so long known later as *Cryptogams*. The second division of the herbs and the whole of the trees he subdivided into Monocotyledons and Dicotyledons, a distinction which has found a place in all succeeding systems.

Ray still further grouped plants together into genera, which were equivalent to our natural orders. Many of them indicated a true knowledge of natural affinities, and are substantially represented at the present day by such natural orders as the Fungi, Musci, Filices, Coniferæ, Labiatæ, Compositæ, Umbelliferæ, and Leguminosæ.

Tournefort, who flourished in France and was a contemporary of Ray, was the first botanist to define genera as we now accept them.

Next in order was the scheme propounded by the celebrated author of the most perfect artificial system ever devised for the arrangement of plants, namely, Linnæus, who, about the year 1738, drew up a sketch of the natural affinities of plants under the name of Fragments. Many of the divisions thus prepared by Linnæus are identical with natural orders as at present defined, among which we may mention Orchideæ, Gramina, Compositæ (nearly), Umbellatæ, Asperifoliæ, Papilionaceæ, Filices, Musci, and Fungi.

Jussieu's Natural System.—To Antoine Laurent de Jussieu, however, belongs the great merit of having first devised a comprehensive natural system. His method was first made known in the year 1789. It was founded upon the systems of Ray and Tournefort, to which he made some important additions, more especially in considering the position of the stamens with respect to the ovary. The following table, which requires no explanation, represents his arrangement.

			Class.
Acotyledons			1. Acotyledones.
Monocotyledons		Stamens hypogynous.	2. Monohypogynæ.
		Stamens perigynous.	3. Monoperigynæ.
		Stamens epigynous.	4. Monoepigynæ.
Dicotyledons.	Apetalæ	Stamens epigynous.	5. Epistamineæ.
		Stamens perigynous.	6. Peristamineæ.
		Stamens hypogynous.	7. Hypostamineæ.
	Monopetalæ	Corolla hypogynous.	8. Hypocorollæ.
		Corolla perigynous.	9. Pericorollæ.
		Corolla epigynous.	10. Epicorollæ Synantheræ (anthers coherent).
			11. Epicorollæ Corisantheræ (anthers distinct).
	Polypetalæ	Petals epigynous.	12. Epipetalæ.
		Petals hypogynous.	13. Hypopetalæ.
		Petals perigynous.	14. Peripetalæ.
	Diclines irregulares		15. Diclines.

Under these fifteen classes Jussieu arranged 100 natural orders or families. This was the first natural arrangement in which an attempt was made to assign characters to natural orders, but so admirably were these drawn up, that they have formed the basis of all succeeding systematists. Indeed, the limits of a great many of Jussieu's natural orders are identical with those of the present day.

De Candolle's Natural System.—The next system of note after that of Jussieu was that of Augustin Pyramus de Candolle, which was first promulgated in 1813. This system, modified, however, in some important particulars, is that which is most in use at the present day. In the first place, De Candolle divided plants into two great divisions or sub-kingdoms, called

Vasculares or Cotyledoneæ, and Cellulares or Acotyledoneæ, the characters of which he described as follows: –

Division 1. *Vasculares*, or *Cotyledoneæ*; that is, plants possessing both cellular (parenchymatous) tissue and vessels; and having an embryo with one or more cotyledons.

Division 2. *Cellulares*, or *Acotyledoneæ*; that is, plants composed of cellular (parenchymatous) tissue only; and whose embryo is not furnished with cotyledons.

The former division was again divided into two classes, called Exogenæ or Dicotyledoneæ, and Endogenæ or Monocotyledoneæ, the essential characters of which may be thus stated:—

Class 1. *Exogenæ*, or *Dicotyledoneæ*; that is, plants whose vessels are arranged in concentric layers, of which the youngest are the outermost and the softest; and having an embryo with opposite or whorled cotyledons.

Class 2. *Endogenæ*, or *Monocotyledoneæ*; that is, plants whose vessels are arranged in bundles, the youngest being in the middle of the trunk; and having an embryo with solitary or alternate cotyledons.

These classes were again divided into sub-classes or groups. Thus, under the Dicotyledoneæ were placed four groups, named Thalamifloræ, Calycifloræ, Corollifloræ, and Monochlamydeæ. Under the Monocotyledoneæ two groups were placed, called Phanerogamæ and Cryptogamæ. The latter group included what are now called the Vascular Cryptogams, or Pteridophyta. The Acotyledoneæ were also divided into two groups, called Foliosæ and Aphyllæ.

The following is a tabular view of De Candolle's system.

Sub-Kingdom 1. VASCULARES, OR COTYLEDONEÆ.

Class 1. *Exogenæ*, or *Dicotyledoneæ*.

Sub-Class 1. *Thalamifloræ*	Petals distinct, inserted with the stamens on the thalamus.
2. *Calycifloræ*	Petals distinct or more or less united, and inserted on the calyx.
3. *Corollifloræ*	Petals united, and inserted on the thalamus.
4. *Monochlamydeæ*	Having only a single circle or floral envelopes, or none.

Class 2. *Endogenæ*, or *Monocotyledoneæ*.

Sub-Class 1. *Phanerogamæ*	Fructification visible, regular.
2. *Cryptogamæ*	Fructification hidden, unknown, or irregular.

The first sub-class comprised the true Monocotyledons except Naiadeæ, which were included with the Vascular Cryptogams in the second.

Sub-Kingdom 2. CELLULARES, OR ACOTYLEDONEÆ.

Sub-Class 1. *Foliosæ*	Having leaf-like expansions, and known sexes.
2. *Aphyllæ*	Having no leaf-like expansions, and no known sexes.

Under these sub-classes De Candolle arranged 161 Natural Orders. As examples of these we may mention the following : of *Thalamifloræ*—Cruciferæ, Caryophylleæ, and Malvaceæ ; of *Calycifloræ*—Rosaceæ, Umbelliferæ, and Compositæ ; of *Corollifloræ*—Convolvulaceæ, Solaneæ, and Labiatæ ; of *Monochlamydeæ*—Polygoneæ, Urticeæ, and Amentaceæ ; of *Phanerogamæ*—Orchideæ, Irideæ, and Gramineæ ; of *Cryptogamæ*—Filices, Equisetaceæ, and Lycopodineæ ; of *Foliosæ*—Musci and Hepaticæ ; and of *Aphyllæ*—Lichenes, Fungi, and Algæ.

In this system it will be observed that De Candolle adopted the primary divisions of Jussieu, but he reversed the order of their arrangement; for instead of commencing with Acotyledons, and passing through Monocotyledons to Dicotyledons, he began with the latter, and proceeded by the Monocotyledons to Acotyledons. He took a retrograde step in placing the Vascular Cryptogams with the Monocotyledons.

Since the appearance of De Candolle's system numerous other arrangements have been proposed by botanists, as those of Agardh, Perleb, Dumortier, Bartling, Lindley, Schultz, Endlicher, and many others. The important work of Robert Brown dates from only a little later than this system of De Candolle. In 1827 he published his discovery of the direct application of the pollen grain to the ovule in Coniferæ and Cycadeæ, which were at that time considered to belong to the Dicotyledons. Thus began the division into Gymnosperms and Angiosperms. At first both these were held to be sections of Dicotyledons, and it was not understood that the Gymnosperms were a lower type. As all these systems, with the exception of those of Lindley and Endlicher, were never much used, and are not adopted in great systematic works of the present day, it will be unnecessary for us to allude to them further. But both the latter having been used in important systematic works, it will be advisable for us to give a general sketch of their leading characters.

ENDLICHER'S NATURAL SYSTEM.—The system of Endlicher is adopted in his 'Genera Plantarum,' published between the years 1836–1840. The following is a sketch of this system. He first divided plants into two great divisions, which he denominated *Regions*, and named *Thallophyta* and *Cormophyta*. These were again divided into *Sections* and *Cohorts*, as follows:—

Region 1. THALLOPHYTA. Plants with no opposition of stem and root; with no vessels and no sexual organs; and with germinating spores lengthening in all directions.

Section 1. *Protophyta.* Plants developed without soil; drawing nourishment from the element in which they grow; and having a vague fructification; as in Algæ and Lichenes.

Section 2. *Hysterophyta.* Plants formed on languid or decaying organisms; nourished from a matrix; all the organs developing at once, and perishing in a definite manner; as in Fungi.

Region 2. CORMOPHYTA. Plants with stem and root in opposite directions; spiral vessels and sexual organs distinct in the more perfect.

Section 3. *Acrobrya.* Stem growing at the point only, the lower part being unchanged, and only used for conveying fluids.

Cohort 1. *Anophyta.* Having no spiral vessels; both sexes perfect; spores free in spore-cases. Examples, Hepaticæ and Musci.

Cohort 2. *Protophyta.* Having vascular bundles more or less perfect; male sex absent. Spores free in one- or many-celled spore-cases. Examples, Filices and Equisetaceæ.

Cohort 3. *Hysterophyta.* Having perfect sexual organs; seeds without an embryo, polysporous; parasitic. Example, Rhizantheæ.

Section 4. *Amphibrya.* Stem growing at the circumference. Examples, Gramineæ, Liliaceæ, Iridaceæ, Orchidaceæ, and Palmaceæ.

Section 5. *Acramphibrya.* Stem growing at both the apex and circumference.

Cohort 1. *Gymnospermæ.* Ovules naked, receiving impregnation immediately by the micropyle; as in Coniferæ.

Cohort 2. *Apetalæ.* Calyx absent, rudimentary, or simple, calycine or coloured, free or united to the ovary. Examples, Cupuliferæ, Urticaceæ, and Polygoneæ.

Cohort 3. *Gamopetalæ.* Both floral envelopes present, the outer calycine, the inner corolline, the latter being monopetalous; rarely abortive. Examples, Compositæ, Labiatæ, Scrophularineæ, and Ericaceæ.

Cohort 4. *Dialypetalæ.* Both floral envelopes present, the outer being monosepalous or polysepalous, free or united to the ovary, calycine or sometimes corolline; the inner being corolline with distinct petals, or rarely cohering by means of the base of the stamens, and with an epigynous, perigynous, or hypogynous insertion; rarely abortive. Examples, Umbelliferæ, Ranunculaceæ, Cruciferæ, Caryophylleæ, Rosaceæ, and Leguminosæ.

Under these divisions Endlicher included 277 Natural Orders. Like Jussieu, he commenced with the simplest plants and gradually proceeded to the more complicated, placing those of the Leguminosæ at the highest point of the series.

LINDLEY'S NATURAL SYSTEM.—To Lindley especially belongs the merit of having been the first botanist who made any serious attempt to introduce a natural arrangement of plants into use in this country. The first system proposed by him in 1830 was but a slight modification of that of De Candolle. No attempt was made in this system to form minor groups or divisions of the tribes; but in 1833, in a new system, Lindley arranged the natural orders in groups subordinate to the higher divisions, which were called *Nixus* (tendencies). These primary divisions were again divided into *Sub-classes*, *Cohorts*, and Nixus or groups of nearly allied *Natural Orders*. In 1838 Lindley again altered his arrangement so far as regarded Exogens; and finally, in the year 1845, further modified his views, and proposed the following scheme, which was that adopted by him in his great work on 'The Vegetable Kingdom.'

1. Asexual, or Flowerless Plants.

Stem and leaves undistinguishable . Class 1. Thallogens.
Stem and leaves distinguishable . . Class 2. Acrogens.

2. Sexual, or Flowering Plants.

Fructification springing from a thallus Class 3. Rhizogens.
Fructification springing from a stem.
  Wood of stem youngest in the centre; cotyledon single.
    Leaves parallel-veined, permanent; wood of the stem always confused . . . . Class 4. Endogens.
    Leaves net-veined, deciduous; wood of the stem, when perennial, arranged in a circle with a central pith . . . . Class 5. Dictyogens.
  Wood of stem youngest at the circumference, always concentric; cotyledons two or more.
    Seeds quite naked . . . Class 6. Gymnogens.
    Seeds enclosed in seed-vessels . Class 7. Exogens.

The Exogens were further divided into four sub-classes thus:

Sub-Class 1. *Diclinous Exogens*, or those with unisexual flowers, and without any customary tendency to form hermaphrodite flowers.
Sub-Class 2. *Hypogynous Exogens*, or those with hermaphrodite or polygamous flowers; and stamens entirely free from the calyx and corolla.
Sub-Class 3. *Perigynous Exogens*, or those with hermaphrodite or polygamous flowers; and with the stamens growing to the side of either the calyx or corolla; ovary superior, or nearly so.
Sub-Class 4. *Epigynous Exogens*, or those with hermaphrodite or polygamous flowers, and with the stamens growing to the side either of the calyx or corolla; ovary inferior, or nearly so.

None of the other classes are divided into sub-classes, but of Endogens four sections are distinguished thus:—

1. Flowers glumaceous (that is to say, composed of bracts not collected in true whorls, but consisting of imbricated colourless or herbaceous scales).

2. Flowers petaloid, or furnished with a true calyx or corolla, or with both, or absolutely naked; unisexual (that is, having sexes altogether in different flowers, without half-formed rudiments of the absent sexes being present).
3. Flowers furnished with a true calyx and corolla; adherent to the ovary; hermaphrodite.
4. Flowers furnished with a true calyx and corolla, free from the ovary; hermaphrodite.

Under the above classes Lindley includes 303 Natural Orders, which are arranged in fifty-six groups subordinate to the sections, sub-classes, and classes, and which are termed Alliances.

BENTHAM AND HOOKER'S SYSTEM.—The system for the arrangement of the Flowering Plants which is now in vogue in England, and which has entirely superseded that of Lindley, is that which has been devised by Bentham and Hooker. It is set forth in their great work, 'Genera Plantarum,' as follows:—

Division 1. PHANEROGAMIA.
  Sub-division 1. ANGIOSPERMIA.
    Class 1. *Dicotyledones.*
      Sub-Class 1. POLYPETALÆ.
        Series 1. Thalamifloræ.
                2. Discifloræ.
                3. Calycifloræ.
      Sub-Class 2. GAMOPETALÆ or MONOPETALÆ.
        Series 1. Inferæ or Epigynæ.
                2. Superæ.
                3. Dicarpeæ.
      Sub-Class 3. MONOCHLAMYDEÆ or INCOMPLETÆ.
        Series 1. Curvembryæ.
                2. Multiovulatæ aquaticæ.
                3. Multiovulatæ terrestres.
                4. Micrembryæ.
                5. Daphnales.
                6. Achlamydosporeæ.
                7. Unisexuales.
                8. Ordines anomali.
    Class 2. *Monocotyledones.*
        Series 1. Microspermæ.
                2. Epigynæ.
                3. Coronarieæ.
                4. Calycinæ.

Series 5. Nudifloræ.
6. Apocarpæ.
7. Glumaceæ.
Sub-division 2. GYMNOSPERMIA.

The series in the sub-classes Polypetalæ and Gamopetalæ of the above system are further divided into Cohorts as follows :—

Sub-Class 1. POLYPETALÆ.

Series 1. Thalamifloræ.
Cohort 1. Ranales.
2. Parietales.
3. Polygalineæ.
Cohort 4. Caryophyllineæ.
5. Guttiferales.
6. Malvales.

Series 2. Discifloræ.
Cohort 1. Geraniales.
2. Olacales.
Cohort 3. Celastrales.
4. Sapindales.

Series 3. Calycifloræ.
Cohort 1. Rosales.
2. Myrtales.
3. Passiflorales.
Cohort 4. Ficoidales.
5. Umbellales.

Sub-Class 2. GAMOPETALÆ.

Series 1. Inferæ or Epigynæ.
Cohort 1. Rubiales.
2. Asterales.
Cohort 3. Campanales.

Series 2. Superæ.
Cohort 1. Ericales.
2. Primulales.
Cohort 3. Ebenales.

Series 3. Dicarpeæ or Bicarpellatæ.
Cohort 1. Gentianales.
2. Polemoniales.
Cohort 3. Personales.
4. Lamiales.

No division of the series of the Monochlamydeæ or of the Monocotyledons is made in 'Genera Plantarum;' but in the English translation of Le Maout and Decaisne's 'Traité Général de Botanique,' which was edited by Sir J. D. Hooker, another classification of them is adopted as follows :—

Sub-Class 3. MONOCHLAMYDEÆ.

Division 1. Ovary superior (*Superæ*).
Cohort 1. Chenopodiales.
2. Laurales.
3. Daphnales.
4. Urticales.
Cohort 5. Amentales.
6. Euphorbiales.
7. Piperales.
8. Nepenthales.

Division 2. Ovary inferior (*Inferæ*).
Cohort 1. Asarales.
2. Quernales.
Cohort 3. Santalales.

Class 2. *Monocotyledones.*

Division 1. Ovary inferior (*Inferæ*).
Cohort 1. Hydrales.
2. Amomales.
3. Orchidales.
Cohort 4. Taccales.
5. Narcissales.
6. Dioscorales.

Division 2. Ovary superior (*Superæ*).
Sub-division 1. Ovary apocarpous (*Apocarpæ*).
Cohort 1. Triurales.
Cohort 2. Potamales.

Sub-division 2. Ovary syncarpous (*Syncarpæ*).
Cohort 1. Palmales.
2. Arales.
3. Liliales.
4. Pontederales.
Cohort 5. Commelynales.
6. Restiales.
7. Glumales.

The classification of Bentham and Hooker has in the main been followed in this volume, and a description of the several Natural Orders of the 'Genera Plantarum' will be found in a subsequent section.

A somewhat different classification has been adopted in England by Vines, which is as follows:—

Monocotyledones.

Sub-Class 1. SPADICIFLORÆ.

Cohort 1. Arales.
Order 1. Araceæ.
2. Lemnaceæ.
3. Pandanaceæ.
Order 4. Cyclanthaceæ.
5. Typhaceæ.

Cohort 2. Palmales.
Order 1. Palmaceæ.

Sub-Class 2. GLUMIFLORÆ.

Cohort 1. Glumales.
Order 1. Graminaceæ.
Order 2. Cyperaceæ.

Cohort 2. Restiales.
Order 1. Eriocaulonaceæ.
Order 2. Restiaceæ.

Sub-Class 3. PETALOIDEÆ.

Series 1. *Hypogynæ.*
Sub-series 1. Apocarpæ.
Cohort 1. Alismales.
Order 1. Naiadaceæ.
2. Juncaginaceæ.
Order 3. Alismaceæ.
4. Butomaceæ.

Sub-series 2. Syncarpæ.

Cohort 1. Commelynales.

Order 1. Xyridaceæ.
Order 2. Commelynaceæ.

Cohort 2. Liliales.

Order 1. Liliaceæ.
2. Juncaceæ.
Order 3. Pontederiaceæ.

Series 2. *Epigynæ.*

Cohort 1. Hydrales.

Order 1. Hydrocharidaceæ.

Cohort 2. Dioscoreales.

Order 1. Dioscoreaceæ.
2. Taccaceæ.
Order 3. Bromeliaceæ.

Cohort 3. Ammomales (*Scitamineæ*).

Order 1. Musaceæ.
2. Zingiberaceæ.
Order 3. Marantaceæ.

Cohort 4. Orchidales.

Order 1. Orchidaceæ.

Cohort 5. Narcissales.

Order 1. Amaryllidaceæ.
Order 2. Iridaceæ.

Dicotyledones.

Sub-Class 1. MONOCHLAMYDEÆ.

Cohort 1. Piperales.

Order 1. Piperaceæ.
2. Chloranthaceæ.
Order 3. Sauruaceæ.

Cohort 2. Urticales.

Order 1. Urticaceæ.
2. Moraceæ.
Order 3. Cannabinaceæ.
4. Ulmaceæ.

Cohort 3. Amentales.

Order 1. Betulaceæ.
2. Corylaceæ.
3. Fagaceæ.
4. Juglandaceæ.
Order 5. Myricaceæ.
6. Casuarinaceæ.
7. Salicaceæ.

Cohort 4. Proteales.

Order 1. Proteaceæ.

Cohort 5. Chenopodiales.

Order 1. Chenopodiaceæ.
2. Amarantaceæ.
Order 3. Phytolaccaceæ.
4. Nyctaginaceæ.

Cohort 6. Asarales.

Order 1. Aristolochiaceæ.
Order 2. Cytinaceæ.

Cohort 7. Santalales.

Order 1. Santalaceæ.
2. Loranthaceæ.
Order 3. Balanophoraceæ.

Sub-Class 2. Polypetalæ.

Series 1. *Thalamifloræ.*

Cohort 1. Ranales.

Order 1. Ranunculaceæ.
2. Magnoliaceæ.
Order 3. Calycanthaceæ.
4. Nymphæaceæ.

Cohort 2. Menispermales.

Order 1. Menispermaceæ.
2. Berberidaceæ.
3. Lauraceæ.
Order 4. Myristicaceæ.
5. Polygonaceæ.
6. Ceratophyllaceæ.

Cohort 3. Caryophyllales.

Order 1. Caryophyllaceæ.
2. Portulaceæ.
Order 3. Aizoaceæ.

Cohort 4. Parietales.

Order 1. Papaveraceæ.
2. Fumariaceæ.
3. Cruciferæ.
4. Capparidaceæ.
Order 5. Resedaceæ.
6. Bixaceæ.
7. Violaceæ.

Cohort 5. Sarraceniales.

Order 1. Sarraceniaceæ.
2. Nepenthaceæ.
Order 3. Droseraceæ.

Cohort 6. Guttiferales.

Order 1. Hypericaceæ.
2. Tamaricaceæ.
3. Elatinaceæ.
Order 4. Ternstrœmiaceæ.
5. Clusiaceæ.
6. Dipterocarpaceæ.

Cohort 7. Malvales.

Order 1. Tiliaceæ.
2. Sterculiaceæ.
Order 3. Malvaceæ.

Series 2. *Discifloræ.*

Cohort 1. Geraniales.

Order 1. Geraniaceæ.
2. Linaceæ.
3. Erythroxylaceæ.
4. Oxalidaceæ.
5. Balsaminaceæ.
6. Tropæolaceæ.
Order 7. Zygophyllaceæ.
8. Rutaceæ.
9. Meliaceæ.
10. Simarubaceæ.
11. Burseraceæ.

Cohort 2. Sapindales.

Order 1. Sapindaceæ.
2. Aceraceæ.
Order 3. Polygalaceæ.
4. Anacardiaceæ.

Cohort 3. Celastrales.

Order 1. Celastraceæ.
2. Staphyleaceæ.
3. Aquifoliaceæ.
4. Thymelaceæ.
Order 5. Elæagnaceæ.
6. Rhamnaceæ.
7. Ampelidaceæ.

Cohort 4. Euphorbiales.

Order 1. Euphorbiaceæ.
2. Buxaceæ.
Order 3. Empetraceæ.
4. Callitrichaceæ.

Series 3. *Calyciforæ.*

Cohort 1. Umbellales.

Order 1. Umbelliferæ.
2. Araliaceæ.
Order 3. Cornaceæ.

Cohort 2. Passiflorales.

Order 1. Passifloraceæ.
2. Papayaceæ.
3. Begoniaceæ.
Order 4. Cucurbitaceæ.
5. Cactaceæ.

Cohort 3. Myrtales.

Order 1. Onagraceæ.
2. Haloragidaceæ.
3. Lythraceæ.
Order 4. Myrtaceæ.
5. Rhizophoraceæ.

Cohort 4. Rosales.

Order 1. Rosaceæ.
2. Leguminosæ.
Order 3. Platanaceæ.

Cohort 5. Saxifragales.

Order 1. Saxifragaceæ.
2. Crassulaceæ.
3. Cephalotaceæ.
Order 4. Pittosporaceæ.
5. Hamamelidaceæ.
6. Podostemaceæ.

Sub-Class 3. GAMOPETALÆ.

Series 1. *Hypogynæ.*

Cohort 1. Lamiales.

Order 1. Labiatæ.
2. Verbenaceæ.
Order 3. Globulariaceæ.

Cohort 2. Personales.

Order 1. Scrophulariaceæ.
2. Plantaginaceæ.
3. Bignoniaceæ.
4. Acanthaceæ.
Order 5. Gesneraceæ.
6. Orobanchaceæ.
7. Lentibulariaceæ.

Cohort 3. Polemoniales.

Order 1. Convolvulaceæ.
2. Polemoniaceæ.
Order 3. Solanaceæ.
4. Boraginaceæ.

Cohort 4. Gentianales.

Order 1. Gentianaceæ.
2. Loganiaceæ.
3. Apocynaceæ.
Order 4. Asclepiadaceæ.
5. Oleaceæ.

Cohort 5. Ebenales.

Order 1. Sapotaceæ.
2. Ebenaceæ.
Order 3. Styraceæ.

Cohort 6. Primulales.

Order 1. Primulaceæ.
2. Myrsinaceæ.
Order 3. Plumbaginaceæ.

Cohort 7. Ericales.

Order 1. Ericaceæ.
2. Epacridaceæ.
3. Diapensiaceæ.
Order 4. Pyrolaceæ.
5. Vacciniaceæ.

Series 2. *Epigynæ.*

Cohort 1. Campanales.

Order 1. Campanulaceæ.
Order 2. Lobeliaceæ.

Cohort 2. Rubiales.

Order 1. Rubiaceæ.
Order 2. Caprifoliaceæ.

Cohort 3. Asterales.

Order 1. Valerianaceæ.
2. Dipsaceæ.
Order 3. Compositæ.

The grouping of the Dicotyledons into the three sub-classes Monochlamydeæ, Polypetalæ, and Gamopetalæ, has been severely criticised from many points of view by several botanists, and has been generally abandoned on the Continent. The relationships of many of the groups originally placed in the first sub-class have been traced with tolerable certainty to many of the Natural Orders of the other two, and from time to time Natural Orders have been removed from them and intercalated among the others. In a system suggested by Braun in 1864, most of them were so distributed; and in 1867 Hanstein so classified them all, making but two sub-classes, which he called Gamopetalæ and Eleutheropetalæ.

This division was opposed by Sachs, who claimed that the union or freedom of the petals was not a sufficiently important point to be the grounds of such a classification. He pointed out that among the Eleutheropetalæ, flowers occur which differ greatly from one another not only in this but also in every other respect; whilst, on the other hand, the most intimate relationship exists between particular sections of the two sub-classes, Sachs suggested the following scheme :—

Monocotyledones.

Series 1. Helobiæ.

- Order 1. Centrospermæ.
- 2. Polycarpæ.
- Order 3. Hydrocharideæ.

Series 2. Micranthæ.

- Order 4. Spadicifloræ.
- 5. Glumifloræ.
- Order 6. Enantioblastæ.

Series 3. Corollifloræ.

- Order 7. Liliifloræ.
- 8. Ananasineæ.
- Order 9. Scitamineæ.
- 10. Gynandræ.

Dicotyledones.

1. Julifloræ.
   - A. Piperineæ.
   - B. Urticineæ.
   - C. Amentiferæ.
2. Monochlamydeæ.
   - A. Serpentarieæ.
   - B. Rhizantheæ.
3. Aphanocyclæ.
   - A. Hydropeltidineæ.
   - B. Polycarpæ.
   - C. Crucifloræ.
4. Tetracyclæ.
   - (*a*) Gamopetalæ.
     - A. Anisocarpæ.
     - B Isocarpæ.
   - (*β*) Eleutheropetalæ.
     - C. Encyclæ.
     - D. Centrospermæ.
     - E. Discophoræ.
5. Perigynæ.
   - A. Calycifloræ.
   - B. Corollifloræ.

Each of these divisions was further classified into smaller groups of Natural Orders, or series of Natural Orders.

Several other systems have been used in recent years on the continent of Europe, of which the most important have been those of Prantl, of Eichler, and of Engler. Eichler's system has been somewhat modified by Warming, and has been received with favour in England as well as abroad.

System of Prantl.—In this system the main divisions into Gymnosperms and Angiosperms, and of the latter into Monocotyledons and Dicotyledons, are observed as in the English systems. The classification of the last two groups is different.

Monocotyledones.

Series 1. Helobiæ.

- Order 1. Fluviales.
- 2. Polycarpicæ.
- Order 3. Hydrocharideæ.

Series 2. Micranthæ.

Order 4. Spadicifloræ.
5. Glumaceæ.
Order 6. Enantioblastæ.

Series 3. Corollifloræ.

Order 7. Liliifloræ.
8. Scitamineæ.
Order 9. Gynandræ.

Dicotyledones.

Sub-Class 1. JULIFLORÆ.

Order 1. Piperinæ.
2. Urticinæ.
Order 3. Amentaceæ.

Sub-Class 2. MONOCHLAMYDEÆ.

Order 4. Serpentariæ.
5. Rhizantheæ.
Order 6. Balanophoreæ.
7. Santalinæ.

Sub-Class 3. ELEUTHEROPETALÆ.

A. Tricoccæ.

Order 8. Tricoccæ.

B. Centrospermæ.

Order 9. Polygoniæ.
Order 10. Caryophyllinæ.

C. Apanocyclicæ.

Order 11. Polycarpicæ.
12. Crucifloræ.
Order 13. Cistifloræ.
14. Columniferæ.

D. Eucyclicæ.

Order 15. Gruinales.
16. Terebinthinæ.
Order 17. Æsculinæ.
18. Frangulinæ.

E. Calycifloræ.

Order 19. Umbellifloræ.
20. Saxifraginæ.
21. Passiflorinæ.
22. Opuntinæ.
Order 23. Myrtifloræ.
24. Rosifloræ.
25. Leguminosæ.
26. Thymelæinæ.

Sub-Class 4. GAMOPETALÆ.

A. Isocarpeæ.

Order 27. Primulinæ.
28. Diospyrinæ.
Order 29. Bicornes.

B. Anisocarpeæ.

1. Hypogynæ.

Order 30. Diandræ.
31. Contortæ.
Order 32. Tubifloræ.
33. Labiatæfloræ.

2. Epigynæ.

Order 34. Campanulinæ.
Order 35. Aggregatæ.

This system somewhat closely resembles that which was adopted by Sachs.

WARMING'S SYSTEM.—A system which has met with much acceptance on the Continent has been devised by Warming, which is based to a large extent upon that of Eichler (1883). In this arrangement the Gymnosperms are divided into three classes instead of three Natural Orders, viz. Coniferæ, Cycadeæ, and Gnetaceæ. The Angiosperms are classified as under. It will be seen that in this system, as in other German systems, the sub-classes of De Candolle and his successors have been abandoned.

ANGIOSPERMÆ.
Class 1. *Monocotyledones.*

Family 1. Helobieæ.
Order 1. Juncaginaceæ.
2. Potamogetonaceæ.
3. Aponogetonaceæ.
Order 4. Naiadaceæ.
5. Alismaceæ.
6. Hydrocharitaceæ.

Family 2. Glumifloræ.
Order 1. Juncaceæ.
2. Cyperaceæ.
Order 3. Gramineæ.

Family 3. Spadicifloræ.
Order 1. Palmeæ.
2. Cyclanthaceæ.
3. Pandanaceæ.
Order 4. Typhaceæ.
5. Araceæ.
6. Lemnaceæ.

Family 4. Enantioblastæ.
Order 1. Commelinaceæ.
2. Magacaceæ.
3. Xyridaceæ.
4. Rapateaceæ.
Order 5. Eriocaulaceæ.
6. Restiaceæ.
7. Centrolepidaceæ.

Family 5. Liliifloræ.
Order 1. Colchicaceæ.
2. Liliaceæ.
3. Convallariaceæ.
4. Pontederiaceæ.
5. Amaryllidaceæ.
Order 6. Bromeliaceæ.
7. Hæmodoraceæ.
8. Iridaceæ.
9. Dioscoriaceæ.

Family 6. Scitamineæ.
Order 1. Musaceæ.
2. Zingiberaceæ.
Order 3. Cannaceæ.
4. Marantaceæ.

Family 7. Gynandræ.
Order 1. Burmanniaceæ.
Order 2. Orchidaceæ.

Class 2. *Dicotyledones.*

Sub-Class 1. CHORIPETALÆ. Petals free.

Family 1. Salicifloræ.

Order 1. Salicaceæ.

Family 2. Casuarinifloræ.

Order 1. Casuarinaceæ.

Family 3. Quercifloræ.

Order 1. Betulaceæ.
2. Corylaceæ.
Order 3. Cupuliferæ.

Family 4. Juglandifloræ.

Order 1. Juglandaceæ.
Order 2. Myricaceæ.

Family 5. Urticifloræ.

Order 1. Ulmaceæ.
2. Urticaceæ.
Order 3. Moraceæ.
4. Cannabinaceæ.

Family 6. Polygonifloræ.

Order 1. Polygonaceæ.
2. Piperaceæ.
Order 3. Chloranthaceæ.

Family 7. Curvembryæ.

Order 1. Caryophyllaceæ.
2. Amarantaceæ.
3. Chenopodiaceæ.
4. Batidaceæ.
Order 5. Phytolaccaceæ.
6. Portulacaceæ.
7. Nyctaginiaceæ.
8. Aizoaceæ.

Family 8. Cactifloræ.

Order 1. Cactaceæ.

Family 9. Polycarpicæ.

Order 1. Ranunculaceæ.
2. Nymphæaceæ.
3. Ceratophyllaceæ.
4. Anonaceæ.
5. Magnoliaceæ.
6. Calycanthaceæ.
Order 7. Monimiaceæ.
8. Berberidaceæ.
9. Menispermaceæ.
10. Lardizabalaceæ.
11. Lauraceæ.
12. Myristicaceæ.

Family 10. Rhœadinæ.

Order 1. Papaveraceæ.
2 Fumariaceæ.
Order 3. Cruciferæ.
4. Capparidaceæ.

Family 11 Cistifloræ.

Order 1. Resedaceæ.
2. Droseraceæ.
3. Sarraceniaceæ.
4. Nepenthaceæ.
5. Violaceæ.
Order 6. Frankeniaceæ.
7. Tamaricaceæ.
8. Cistaceæ.
9. Bixaceæ.
10. Dilleniaceæ.

Order 11. Elatinaceæ.
12. Hypericaceæ.
13. Guttiferæ.
14. Ternstrœmiaceæ.
Order 15. Rhizoboleæ.
16. Marcgraviaceæ.
17. Dipterocarpaceæ.

Family 12. Gruinales.

Order 1. Oxalidaceæ.
2. Linaceæ.
3. Geraniaceæ.
4. Tropæolaceæ.
Order 5. Balsaminaceæ.
6. Limnanthaceæ.
7. Humiriaceæ.

Family 13. Columniferæ.

Order 1. Sterculiaceæ.
2. Tiliaceæ.
Order 3. Malvaceæ.

Family 14. Tricoccæ.

Order 1. Euphorbiaceæ.
2. Buxaceæ.
Order 3. Callitrichaceæ.
4. Empetraceæ.

Family 15. Terebinthinæ.

Order 1. Connaraceæ.
2. Meliaceæ.
3. Rutaceæ.
4. Burseraceæ.
5. Zygophyllaceæ.
Order 6. Simarubaceæ.
7. Ochnaceæ.
8. Anacardiaceæ.
9. Icacinaceæ.

Family 16. Æsculinæ.

Order 1. Staphyleaceæ.
2. Melianthaceæ.
3. Sapindaceæ.
4. Aceraceæ.
5. Malpighiaceæ.
Order 6. Erythroxylaceæ.
7. Vochysiaceæ.
8. Trigoniaceæ.
9. Tremandraceæ.
10. Polygalaceæ.

Family 17. Frangulinæ.

Order 1. Celastraceæ.
2. Aquifoliaceæ.
Order 3. Ampelidaceæ.
4. Rhamnaceæ.

Family 18. Thymelæinæ.

Order 1. Thymelaceæ.
2. Elæagnaceæ.
Order 3. Proteaceæ.

Family 19. Saxifraginæ.

Order 1. Crassulaceæ.
2. Saxifragaceæ.
3. Ribesiaceæ.
4. Hydrangeaceæ.
Order 5. Pittosporaceæ.
6. Hamamelidaceæ.
7. Platanaceæ.
8. Podostemaceæ.

Family 20. Rosifloræ.

Order 1. Rosaceæ.
2. Amygdalaceæ.
Order 3. Chrysobalanaceæ.
4. Pomaceæ.

Family 21. Leguminosæ.
Order 1. Cæsalpiniaceæ.
2. Papilionaceæ.
Order 3. Mimosaceæ.

Family 22. Passiflorinæ.
Order 1. Passifloraceæ.
2. Papayaceæ.
3. Turneraceæ.
4. Samydaceæ.
Order 5. Loasaceæ.
6. Datiscaceæ.
7. Begoniaceæ.
8. Cucurbitaceæ.

Family 23. Myrtifloræ.
Order 1. Lythraceæ.
2. Blattiaceæ.
3. Melastomaceæ.
4. Œnotheraceæ (Onagraceæ).
Order 5. Haloragidaceæ.
6. Rhizophoraceæ.
7. Combretaceæ.
8. Myrtaceæ.

Family 24. Umbellifloræ.
Order 1. Cornaceæ.
2. Araliaceæ.
Order 3. Umbelliferæ.

Family 25. Hysterophyta.
Order 1. Aristolochiaceæ.
2. Santalaceæ.
3. Loranthaceæ.
Order 4. Rafflesiaceæ.
5. Balanophoraceæ.

Sub-Class 2. SYMPETALÆ. Petals united.

Series 1. Pentacyclicæ.

Family 26. Bicornes.
Order 1. Pyrolaceæ.
2. Ericaceæ.
3. Rhodoraceæ.
Order 4. Diapensiaceæ.
5. Epacridaceæ.
6. Vacciniaceæ.

Family 27. Diospyrinæ.
Order 1. Sapotaceæ.
2. Ebenaceæ.
Order 3. Styracaceæ.

Family 28. Primulinæ.
Order 1. Primulaceæ.
2. Myrsinaceæ.
Order 3. Plumbaginaceæ.

Series 2. Tetracyclicæ.

Family 29. Tubifloræ.
Order 1. Polemoniaceæ.
2. Hydrophyllaceæ.
Order 3. Convolvulaceæ.

Family 30. Personatæ.
Order 1. Solanaceæ.
2. Nolanaceæ.
3. Scrophulariaceæ.
4. Utriculariaceæ.
5. Gesneraceæ.
Order 6. Bignoniaceæ.
7. Pedaliaceæ.
8. Acanthaceæ.
9. Plantaginaceæ

Family 31. Nuculiferæ.

Order 1. Cordiaceæ.
2. Boraginaceæ.
3. Verbenaceæ.
4. Labiatæ.
Order 5. Selaginaceæ.
6. Globulariaceæ.
7. Stilbaceæ.

Family 32. Contortæ.

Order 1. Gentianaceæ.
2. Apocynaceæ.
3. Asclepidaceæ.
4. Loganiaceæ.
Order 5. Oleaceæ.
6. Jasminaceæ.
7. Salvadoraceæ.

Family 33. Rubiales.

Order 1. Rubiaceæ.
Order 2. Caprifoliaceæ.

Family 34. Dipsacales.

Order 1. Valerianaceæ.
2. Dipsacaceæ.
Order 3. Calyceraceæ.

Family 35. Campanulinæ.

Order 1. Campanulaceæ.
2. Cyphiaceæ.
3. Lobeliaceæ.
Order 4. Godeniaceæ.
5. Stylidiaceæ.

Family 36. Aggregatæ.

Order 1. Compositæ.

System of Engler (1892).—In this system the Vegetable Kingdom is divided into four large groups: the *Myxothallophyta*, including only the Myxomycetes; the *Euthallophyta*, embracing the various groups of the Algæ and Fungi; the *Embryophyta zoidiogama*, including the Bryophyta and the Pteridophyta; and the *Embryophyta siphonogama*, in which are placed the Spermaphyta. The latter are classified as under:—

Sub-division 1. GYMNOSPERMÆ.

Class 1. Cycadales.
2. Cordaitales.
3. Bennettitales.
Class 4. Coniferæ.
5. Gnetales.

Sub-division 2. ANGIOSPERMÆ.

Class 1. Chalazogamæ.
Series. Verticellatæ.

Class 2. Acrogamæ.
Sub-Class 1. *Monocotyledoneæ.*

Series 1. Pandanales.
2. Helobiæ.
3. Glumifloræ.
4. Principes.
5. Synanthæ.
Series 6. Spathifloræ.
7. Farinosæ.
8. Liliifloræ.
9. Scitamineæ.
10. Microspermæ.

Sub-Class 2. *Dicotyledoneæ.*

1. Archichlamydeæ.

Series 1. Piperales.
2. Juglandales.
3. Salicales.
4. Fagales.
5. Urticales.
6. Proteales.
7. Santalales.
8. Aristolochiales.
9. Polygonales.
10. Centrospermæ.
11. Ranales.
12. Rhœadales.
Series 13. Sarraceniales.
14. Rosales.
15. Geraniales.
16. Sapindales.
17. Rhamnales.
18. Malvales.
19. Parietales.
20. Opuntiales.
21. Thymelæales.
22. Myrtifloræ.
23. Umbellifloræ.

2. Sympetalæ.

Series 1. Ericales.
2. Primulales.
3. Ebenales.
4. Contortæ.
5. Tubifloræ.
Series 6. Plantaginales.
7. Rubiales.
8. Aggregatæ.
9. Campanulatæ.

It will have been seen that the Natural System now in use in England has been gradually evolved through the working of many observers, extending over many years. There is no reason to suppose that it has yet attained anything like completeness; indeed, many of the groups are still variously placed by different botanists. For the present, however, the Vegetable Kingdom may be conveniently divided into the following four groups:—

I. Thallophyta, including the forms whose vegetative body is commonly a thallus or a thalloid shoot. It rarely shows greater morphological differentiation. The prominent form is the gametophyte, the sporophyte not always occurring.

It is subdivided into:

Class 1. Algæ.
,, 2. Fungi.
,, 3. Lichenes.

II. Bryophyta, or Moss-like plants. The gametophyte is the more prominent form, and regularly alternates with the sporophyte. Differentiation of the body of the former into stem and leaves is general, but the roots are rudimentary or absent.

It includes:

Class 4. Hepaticæ.
,, 5. Musci.

III. Pteridophyta, or Fern-like plants. The sporophyte is the prominent form, the gametophyte being small and not well developed. Considerable differentiation of tissues is found in the sporophyte, and its body exhibits stem, leaves, and roots.

It includes:

Class 6. Filicinæ.
,, 7. Equisetinæ.
,, 8. Lycopodinæ.

IV. Spermaphyta, or Phanerogamia, including all plants which produce seeds. The sporophyte is the predominant form.

The sub-divisions are:

A. Gymnospermæ.
    Class 9. Gymnospermæ.

B. Angiospermæ.
    Class 10. Monocotyledones.
    ,, 11. Dicotyledones.

CHAPTER III.

GROUP I.

THALLOPHYTA.

THIS group includes the Algæ, the Fungi, and the Lichens. It embraces plants of widely different habit and complexity of structure, both morphological and anatomical. In the lowest forms they are characterised by extreme simplicity in both these respects, the plant body being sometimes a single cell, sometimes a thallus consisting of filaments or plates of cells. In the higher forms, on the contrary, the plants are often bulky and formed of masses of tissue showing some considerable histological differentiation; their form may display both root and shoot, the latter exhibiting stem and leaves. On the other hand, these bulky masses may be distinctly thalloid.

FIG. 779.

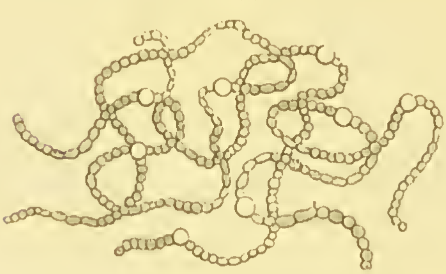


Fig. 779. Filaments from a Nostoc colony. After Luerssen.

The simplest Thallophyte shows no histological differentiation, being only a single cell such as Yeast, or Hæmatococcus. A chain of cells like Nostoc (*fig.* 779) is almost as simple, though cells of two kinds may be present in the chain. Usually a filament of this kind has its cells independent, and separated from each other by cell-walls. In a good many cases these separating walls are not formed, and the organism consists of a tubular body with an external wall, on the inner face of which lie the constituent cells, whose protoplasm is continuous throughout. The composite nature of this structure is recognised by the presence of numerous nuclei. A structure like this is called a *Cœnocyte.*

The filament in other cases is much like this, but some of the separating walls are present, so that the filament is divided into a number of chambers, which are not cells but cœnocytes.

This cœnocytic structure may extend into some of the morphologically most highly complex bodies. Thus the Alga *Caulerpa*, which attains considerable size and whose body shows rounded stems and much-divided leaves, is composed of only a single cœnocyte, whose cavity extends through all the ramifications of the plant. The Fungus *Mucor Mucedo* shows a similar structure (*fig.* 780).

In cases where the Thallophyte is composed of masses of cells there may be considerable histological differentiation, or there may be but little. In some of the brown seaweeds we find a limiting layer, enclosing a very different internal tissue. In some this is composed of elongated loosely arranged cells with mucilaginous cell-walls; in others it shows differentiation into more complex structures. In *Macrocystis*, for example, we find under the epidermal layer a layer of thin-walled parenchyma covering a layer of somewhat prosenchymatous cells with thickened walls, sometimes with pits upon them. The inner portion of this contains the well-marked sieve-tubes already referred to. Some of the large Algæ of the same group as

Fig. 780.

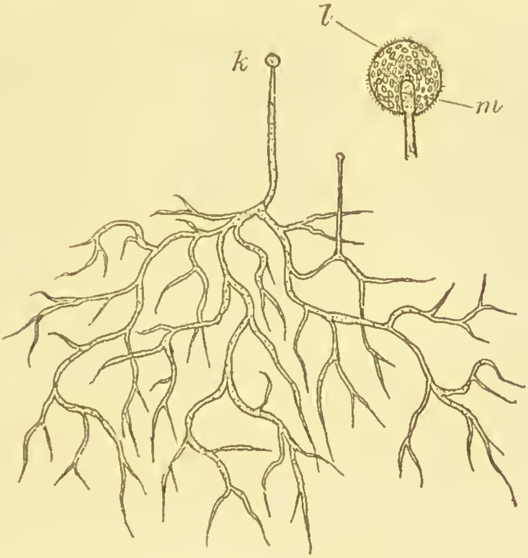


Fig. 780. Cœnocyte of *Mucor Mucedo*.

Macrocystis, the *Laminarias*, show a secondary growth in thickness of the stalk, the merismatic layer being sometimes the epidermal one, and sometimes one specially differentiated near the periphery. In the latter case the growth in thickness resembles that of a Dicotyledon, though the cells formed are different, never becoming lignified nor truly vascular. There is formed in some a kind of axial strand of elongated cells, which can sometimes be traced upwards into the leaves. In some of the plants of the same group certain secretory structures, the *mucus* or *gum passages*, are differentiated. In the masses of tissue constituting the so-called fructifications of the more bulky Fungi, such as *Agaricus*, the structure is composed of filamentous cells or hyphæ arranged side by side and cohering together.

The differentiation of tissue leads also to the localisation of the regions of growth. These are sometimes apical, when the growing points may be convex or depressed; or they may be intercalary.

The form in which the plant exists is always the gametophyte. The sporophyte is either not produced at all, or it forms a small structure not detached from the gametophyte, and sometimes consisting only of a single cell. In but few cases is it a separate structure. There is thus not that regular alternation of generations which we have seen to exist in all the forms above the Thallophytes, where the sporophyte regularly gives rise to the gametophyte and is again reproduced from the latter. This obtains, however, in some cases, particularly in the higher Algæ.

The gametophyte in very many cases produces asexual as well as sexual reproductive cells. These are in structure and mode of behaviour almost exactly like the spores of the sporophyte. To distinguish them from the latter they are often called *gonidia*. In some cases both gonidia and gametes are borne upon the same gametophyte; in others the plant frequently produces gonidia alone. A gametophyte in which no sexual cells arise is spoken of as a *potential* one. In many cases a succession of potential gametophytes occurs, each arising from one of the gonidia of its parent, which succession is sooner or later interrupted by one of the series producing sexual cells. Thus an irregular alternation of generations arises, not between gametophyte and sporophyte, but between actual and potential gametophytes. This is spoken of as *homologous* alternation, to distinguish it from the other kind, which is known as *antithetic*.

A potential gametophyte must not be confused with a sporophyte, though both bear only asexual reproductive cells. The former is capable of bearing sexual cells as well, under appropriate conditions; the latter is not.

As mentioned above, the result of the coalescence of two gametes is sometimes the production of a sporophyte. Very often, however, the process only gives rise to another gametophyte.

The same plant body produces thus both sexual and asexual cells. In this lowly class of plants the allotment of these two varieties of reproductive structures each to its appropriate plant body has not yet been reached.

FIG. 781.

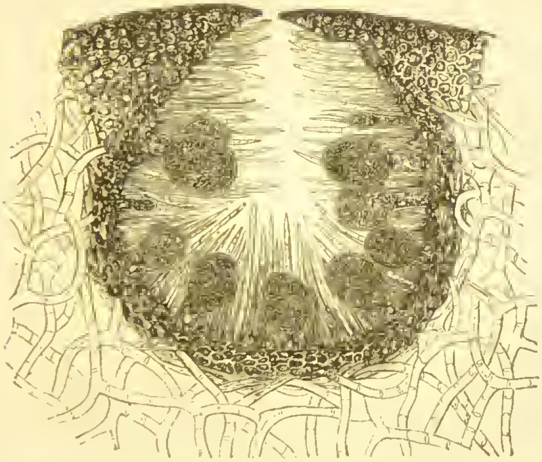


FIG. 782.

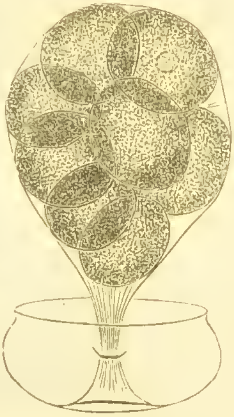


Fig. 781. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.——*Fig.* 782. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.

Above this group each kind is found developed upon its special form, and the two forms regularly alternate.

The gametophyte is the dominant form in the group; the commencement of the development of the sporophyte is indicated in the group of Algæ by the zygospores of many Chlorophyceæ, which produce two or four zoospores on germination, and perhaps by the formation of the cystocarps or fruits of the red seaweeds; in the Fungi by the behaviour of the zygote of the Myxochytridineæ, which gives rise to zoospores, and that of Mucor which produces a rudimentary mycelium, on which is developed a sporangium with its spores.

In the Thallophyta the differentiation of the sexual organs is seldom very complex. The male cells or antherozoids, or spermatozoids, are usually developed in antheridia, often consisting of single cells of the surface. In the Fungi the differentiation into antherozoids, with one doubtful exception, does not take place, and the male organ is only a swollen cell or branch of a hypha, containing usually undifferentiated protoplasm. In most cases the antherozoids are ciliated and consequently motile; in certain groups of both Algæ and Fungi they are non-motile. In this case they become sooner or later clothed with a cell-wall.

The female organ is usually an *oogonium* (*fig.* 782) consisting of a single cell, often carried on a stalk, and containing one or more *oospheres*. In other forms it is an *archicarp* (*fig.* 783) or *procarpium* (*fig.* 784) and does not contain any differentiated oosphere.

FIG. 783.

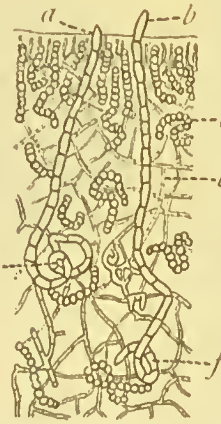


FIG. 784.

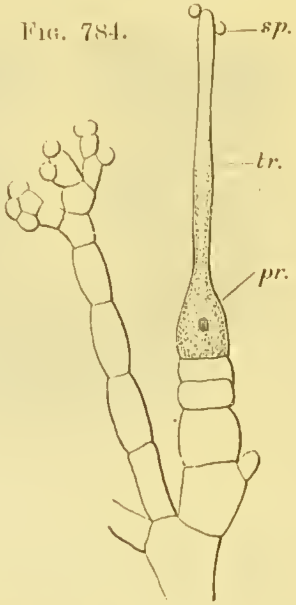


Fig. 783. Section of thallus of a lichen, showing archicarps, *e*, *f*.——*Fig.* 784. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. After Kny.

The Thallophyta are divided into three classes, the Algæ, Fungi, and Lichens. The first contain chlorophyll, the second do not. As a consequence their habit of life is essentially different; the former can prepare food for themselves from the constituents of the air and the medium in or on which they live; the latter are compelled to obtain it directly or indirectly from other organisms. The members of the third class are partly algal and partly fungal.

Class I.—ALGÆ.

As we have already seen, there exists in this group a wonderful variety of forms, ranging from single cells of microscopic dimensions to immense plants showing both morphological and anatomical differentiation. They are mainly aquatic in their habit, being found in both fresh and salt water. Many of the humbler of them occur, not in water, but in moist situations, such as on rocks, banks, tree trunks, &c. Some few forms are epiphytic, living attached to other Algæ by filamentous or more massive outgrowths, which are embedded in the tissues of their hosts. Though epiphytic they are usually not parasites.

They all contain colouring matters of some kind; chlorophyll is always present, but in some it is masked by the presence of other pigments in the chromoplastids. We have blue-green, green, brown, and red Algæ, and the distinguishing colouring matters serve as a primary basis of classification in the group.

The forms that live in fresh water are chiefly green, though there are among them a few red forms, and many which are blue-green. A large number of microscopic forms, belonging to the Diatoms, also inhabit fresh water. These are olive-brown in colour.

The massive forms include representatives of all four colours: their distribution bears a certain relationship to their hue. Thus the seaweeds which are found near the limit of high-water are green; between high- and low-water marks the olive-brown forms are more prominent, while the red forms are also sparsely represented in this area. Beyond low-water mark the olive-green gradually give place to the red forms, and as the depth increases the latter become predominant. They are seldom found beyond a depth of 250 to 300 feet, so that the massive flora occupies a belt along the shore, extending from that depth to the limit of high-water. Some forms are attached to a substratum, others float freely in the water.

The form which the adult plant exhibits is, as we have seen, the gametophyte, either actual or potential. The sporophyte rarely occurs, and then only in a few of the higher members of the green, brown, and red forms.

In histological differentiation the Algæ are all very simple as compared with the higher plants. Many of them are unicellular and multiply by ordinary fission; each cell-division so produces a new plant. In others the cells do not separate from each other, but the division proceeds until a long filament of cells is formed, each cell being generally physiologically independent, though connected anatomically with the others. In other cases the cells divide in two planes, forming a plate of cells. Sometimes the unicellular forms do not separate from each other after division, but remain connected by a common mucilaginous cell-wall, forming a colony or *cœnobium*. In other Algæ the structure is a cœnocyte, no cell-walls being formed in the interior of the filament, which thus appears unicellular. In the larger cœnocytes, as *Caulerpa*, the cavity is often crossed by trabeculæ of modified cellulose. In the higher forms the plant is multicellular, and shows a rudimentary differentiation of tissues; a kind of epidermis often being distinguishable from a central tissue, which is sometimes furnished with sieve-tubes. In the stalks of some Laminarias there is a secondary meristem which increases the thickness of the part. In many of the Phæophyceæ the internal cells are hypha-like, and loosely arranged with mucilaginous walls and large intercellular spaces (*fig.* 785). There is sometimes a fair amount of morphological differentiation; generally the plant body is a thallus, but frequently rudimentary roots can be distinguished, serving as organs of attachment. The plant is often attached to its substratum by

FIG. 785.

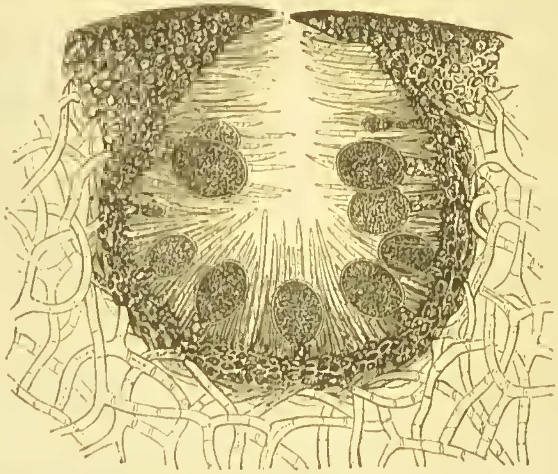


Fig. 785. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.

special discs or outgrowths from the stem known as *haptera*. The shoot in many cases may show differentiation into stem and leaf, sometimes of very delicate form. Instances may be found in *Caulerpa*, *Chara*, *Sargassum*, and others.

The mode of growth in length of the thallus or thalloid shoot also varies a good deal. There are often definite growing points, which may be either apical or intercalary. When they are apical they sometimes consist of a simple apical cell, as they do in the Ferns and their allies ; or they may be composed of a number of cells. These may be disposed in a series along the margin of the thallus, or may form a group resembling the apical meristem of the Phanerogams. In the cœnocytes, though these grow at their apices, no apical cell is differentiated. When the growth in length is intercalary, there is often a definite growing zone in the frond, but sometimes this is not the case, any cell being capable of division. Sometimes the growing point consists of a terminal hair, or collection of hairs, the basal cells of which are merismatic. In most filamentous forms, any cell of the filament can divide, and so increase the length of the filament.

Where secondary growth in thickness takes place it may be brought about in two ways. In the stalks of some of the Laminarias a secondary meristem or cambium is developed, either in the epidermal cells or those immediately beneath them. This behaves as in woody Dicotyledons, producing new tissue on both sides. The external tissue forms a pseudo-bark or rind, while the internal adds to the substance of the stalk. The central stalk tissue is a dense plexus of filaments which anastomose freely with each other. In *Desmarestia* a sort of mantle or covering of the original axis is produced by filaments which grow from the cells of the lateral branches originating just below the growing point, which become united together and to the original axis, subsequently undergoing differentiation into cortical and internal tissues.

With the exception of the lowest group the colouring matters are associated with definite chromatophores, which may occur singly or in numbers in the cells. The pigments which are formed are *phycoerythrine* in the red, *phycoxanthine* and *phycophæine* in the brown, and *phycocyanine* in the blue-green Algæ. Besides these, all the members of the group contain chlorophyll, which is the only colouring matter in the green forms. The other pigments may be extracted by fresh cold water, which dissolves all but the chlorophyll. The disposition of the chromatophores is very constant in the several species. In some of them curious bodies called *pyrenoids* are found, which are probably connected with the assimilative processes.

The group exhibits considerable variety in its modes of sexual reproduction. In the simplest forms that show sexuality, the gametes are not distinguishable into male and female. In *Ulothrix* (*fig.* 803) the contents of some cells break up into a number of ciliated masses of protoplasm which escape from the cell, and, after swimming about for a while, conjugate in pairs. In the *Zygnemeæ* and *Mesocarpeæ* the gametes are solitary and not motile, and do not escape from the cells in which they are formed. In *Cutleria* the gametes are dissimilar in size, but both are ciliated. The larger comes to rest soonest, and one of the smaller fuses with it. More completely differentiated gametes are found in higher forms (*figs.* 787 and 789); oospheres are developed in oogonia and antherozoids in antheridia. When the gametes are alike (*planogametes*) the reproduction is called *isogamous*; when they are different in size and behaviour it is said to be *oogamous*. In the *Rhodophyceæ* the antherozoid is not ciliated and there is no differentiated oosphere. The female organ is known as a *carpogonium*; it is frequently multicellular, and fertilisation is brought about through a filiform or elongated cell known as a *trichogyne*.

Fig. 786.

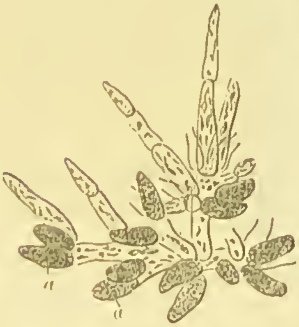


Fig. 787.

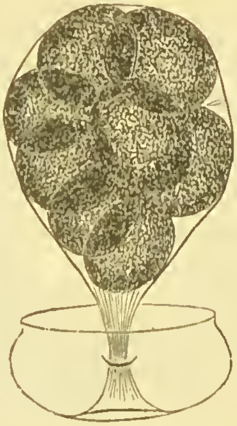


Fig. 788.

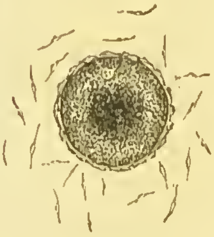


Fig. 786. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret. —*Fig.* 787. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.—*Fig.* 788. An oosphere without a cellulose coat, surrounded by motile antherozoids.

The asexual reproductive cells are frequently borne upon the gametophyte. They may be ciliated cells, differing but little, if at all, in appearance from the gametes. These are known as *zoogonidia*, from their power of movement. In other cases they are non-motile. They are at first always naked cells. Sometimes they are developed in special organs, the *gonidangia*; in some forms any cell of the thallus may produce them. Where the sporophyte exists it gives rise to spores similar in structure to the gonidia. In many of the green Algæ the zygote or fertilised cell gives rise to a number of zoospores, either with or without preliminary cell-division. It may in such cases be regarded as a very rudimentary sporophyte.

Fig. 789.

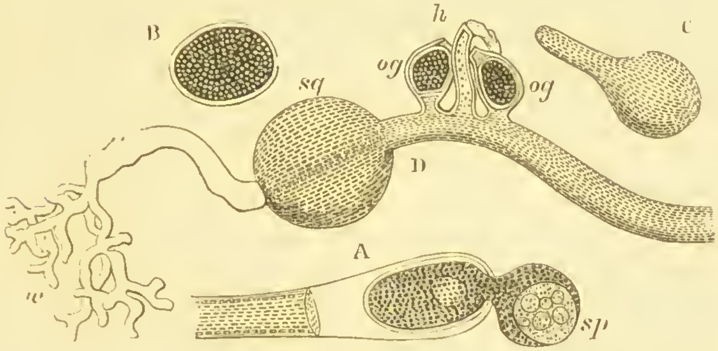


Fig. 789. A. *sp.* Newly formed zoocœnocyte of *Vaucheria sessilis* escaping. B. The same at rest after having lost its cilia. C. First stage of germination. D. Filament of *Vaucheria sessilis* producing oogonia, *og*, *og*, and antheridium, *h*. *w*. Hyaline root-like process, forming a sort of mycelium. *sq*. Zoocœnocyte, which by germinating has formed the filament. After Sachs.

Fig. 790.

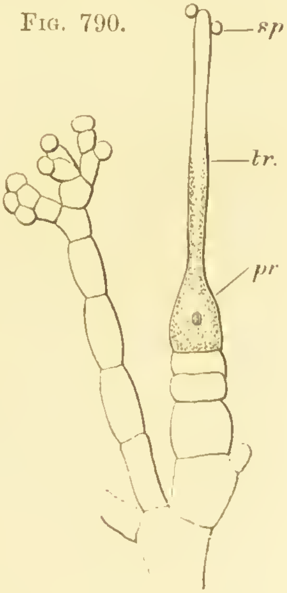


Fig. 790. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. After Kny.

Vegetative reproduction is very common in the lower forms; in the unicellular Algæ, each cell-division is often followed by a separation of the cells, showing thus the simplest example of this mode. In *Sphacelaria*, gemmæ are produced which are multicellular. *Chara* gives rise also to similar bodies and to peculiar structures, the *embryonic branches*, which are referable to this mode of reproduction.

The main sub-divisions of the Algæ are based upon the colour of the thallus. This distinction would be of little value in itself, but the groups so defined show peculiarities of form and of life history which warrant their being considered as sub-classes. The divisions are Cyanophyceæ (blue-green), Phæophyceæ, and Diatomaceæ (olive-brown), Rhodophyceæ (red), and Chlorophyceæ (green).

Sub-Class I.—Cyanophyceæ.

The forms presented by the members of this group are very simple. In many cases the plant is unicellular, or if it divides, the products of the division remain surrounded by a common cell-wall, which becomes mucilaginous and of considerable thickness, so that the cells appear as if embedded in a mass of jelly. The plane of division may be such as to cause the cells to form a flat plate, or a mass more than one cell in thickness may result. In other cases the cells divide so as to form a filament, often of some length, sometimes tapering at its apex, and either free or attached at its base to some substratum. Usually many filaments are collected together, so that the plant appears in tufts. This filamentous form is also invested with a sheath, of similar consistence to that in the former case. The sheath is often coloured with various tints, purple, blueish, or red. In some cases, such as *Nostoc*, many filaments are embedded in a mass of jelly formed of the thickened sheaths. The cells are not ciliated, but the filaments when free are capable of a peculiar swaying movement, the mechanism of which is not known. The cells are in all cases of very simple structure; no nucleus has been satisfactorily shown to exist, and the phycocyanin or blue-green colouring matter is diffused through the protoplasm; no chromoplastids have been found. The cell-wall has been stated to be formed of a substance resembling cutin, while the sheath is always cellulose, or a modification of it. The reproductive processes are chiefly vegetative; the filaments split up into fragments, which, after a period of inactivity, grow out into filaments like their parent. These fragments, which consist of several cells, are called *hormogonia*. In *Nostoc* the cells of the filament are of two kinds (*fig.* 791); clear cells, almost spherical, named *heterocysts*, occur among the others. These mark the limits of the hormogonia.

The filament sometimes branches, either regularly by the formation of growing points placed laterally, or often irregularly by the hormogonia not becoming completely detached, and so growing while adhering to the filament.

In many forms gonidia are produced. These are single cells of the filament or mass, which are rounded in shape, larger than the other cells, and furnished with a strong thickened cell-wall. They become detached from the plant, and are capable of resting for some time before germinating. In the filamentous forms, when germination takes place, the wall of the gonidium cracks and cell-divisions take place in the cell in such order that a filament is produced much resembling an ordinary hormogonium; this becomes free from the gonidium-coating and develops into the plant. In the other forms, the divisions of the germinating gonidium are irregular and give rise to a mass of cells. Sexual reproduction is unknown in the group.

Fig. 791.

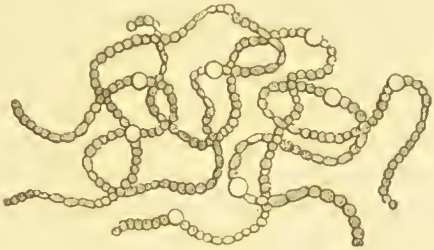


Fig. 791. Filaments from a *Nostoc* colony. After Luerssen.

In habit, some of the Cyanophyceæ are free floating organisms; others are attached by their bases to rocks or stones. Some are held together by their gelatinous coatings to form colonies of various shapes. Some are endophytic and live symbiotically with other plants. *Nostoc* is frequently found associated with a fungus in the thallus of a lichen; it occurs, too, in cavities in the thallus of *Azolla* and in the bodies of *Anthoceros* and of Gunnera. Others again are epiphytic, boring into the tissue of other Algæ and remaining attached to them. A few of them, chiefly abundant in hot springs, are covered with a precipitate or pellicle of carbonate of calcium, which may wrap round the individual filaments, or enclose the whole thallus.

Sub-Class II.—DIATOMACEÆ.

These plants have often been included in the next sub-class, the Phæophyceæ, on account of their olive-brown colour. They are, however, so unlike them in every other respect, while they present no very great resemblance to any other group of Algæ, that it seems best to regard them as a separate sub-class.

There are both fresh-water and marine forms, and they are extremely numerous wherever they occur.

Diatoms are unicellular plants, of very minute size, which have their cell-walls strongly impregnated with silica, the markings upon the walls often being of great regularity and beauty. The plants may be free, or a number of them may be grouped together. In the latter case the colony may consist of a chain of cells, or they may be aggregated together upon gelatinous stalks, or may form gelatinous masses. Each diatom consists of a protoplasmic cell or *frustule* encased in two silicified shells known as *valves*, one of which overlaps the other by its edges. The peculiar sculpturing is found upon the flattened face of each valve. The plant is not furnished with cilia, but is nevertheless capable of a peculiar gliding movement through the water, the nature of which is at present unexplained. The colouring matter is deposited in chromatophores of more or less regular form, and is not diffused through the protoplasm as in the preceding group.

The diatoms frequently undergo longitudinal fission; the two valves slightly separate; the protoplasm divides, and each half secretes a new valve between itself and its fellow, which has its edges included under the rim of the old valve. The two valves of a diatom are thus of different ages. In the free forms this process of fission increases the number of the individuals; in those which continue attached it recalls the processes of intercalary growth.

This repeated bi-partition gradually reduces the size of the diatoms, each new valve being necessarily a little smaller than the one which overlaps it. When a certain limit of size is reached another method of reproduction occurs, which is in some cases a sexual one. This is the formation of *auxospores*. The contents of two diatoms escape from the valves in which they are enclosed, and unite together, growing into a new plant which secretes a pair of valves like those of the original cells. In some cases the process is asexual; the contents of a cell escape and grow; when a considerable size has been attained, new valves are secreted by the protoplasm and the original appearance is resumed.

Certain modifications of both these methods occasionally occur.

Sub-Class III.—PHÆOPHYCEÆ, or Melanophyceæ.

This sub-class includes those Algæ which are of an olive-brown or olive-green colour, with the exception of the Diatomaceæ. Its members comprise forms of very great variety, some being microscopic while others have a plant body several hundreds of feet in length and of considerable thickness. In the simplest cases the body is unicellular, or forms a colony resembling that of many of the Cyanophyceæ. The colony may be attached or not. In other cases the plants, which vary a good deal in size, are attached to rocks by specially differentiated roots, or by haptera. Epiphytic forms occur, filamentous patches being seen upon other Algæ; these are the free portions of the epiphyte, rhizoidal appendages having penetrated the tissues of the host.

The brown colouring matter, which is a mixture of phycophæine and phycoxanthine, is localised in definite plastids or chromatophores, instead of being diffused through the protoplasm of the cells. The anatomical or histological differentiation is sometimes considerable, a great variety of tissues being found in the thallus.

Asexual reproductive cells are found in some of the members of this sub-class, which may be spores or gonidia; sometimes these are motile, sometimes not. Some members of the group possess only sexual reproductive cells.

The sexual organs are sometimes *antheridia*, containing *antherozoids*, and *oogonia*, producing *oospheres*. Fertilisation never takes place in the oogonia, the gametes of both sexes being discharged into the water. The antherozoids are ciliated, the cilia being two in number, attached at the side of the gamete and pointing one towards each end.

More frequently the gametes are alike, or nearly so, when the organ producing them is called a *gametangium*. They are then always ciliated.

The oogonium is always unicellular and produces one or several oospheres; the antheridium may be unicellular or multicellular. In the latter case each cell produces only a single antherozoid.

There is a good deal of variety in the morphological differentiation of the group. Some show only a thallus; others present the appearance of root and shoot, and in many the latter is distinctly leafy. In some, special branches bear the reproductive organs.

Alternation of generations can only be traced in some forms the sporophyte phase is generally absent; it is represented in some of the Cutleriaceæ, though sometimes the two forms are very similar in appearance and can only be distinguished by noticing what kind of reproductive cells they respectively produce

The sub-divisions of the group are very difficult to define, and many schemes of classification have been suggested.

Several different types may with advantage be considered. Of these the FUCACEÆ are most familiar. The thallus is generally of large size and shows a copious branching. In *Cystoseira* and other genera the shoot can be seen to be divided into stem and leaves. *Sargassum* exhibits also branches which in external appearance only resemble fruits. The branches of the thalloid shoot, or the leaves of the leafy forms, often exhibit curious air-chambers which serve as floats. The plants are often attached to the substratum by suckers, or by haptera. The epiphytic forms are secured to their hosts by haustoria, which penetrate the tissues of the latter.

The thallus generally shows histological differentiation. There is an external rind of closely packed cells, in which the colouring matter is abundant. This constitutes a pseudo-epidermis. The innermost layer of this tissue is capable of increasing the thickness of the shoot by repeated tangential divisions, forming in some cases almost a rudimentary bark. Beneath this layer is some thick-walled parenchyma; and this covers in turn a central strand, often of considerable dimensions. The cells of this strand are elongated and narrow, and have their longitudinal walls pitted. They do not, however, become woody, but their walls are usually mucilaginous and much swollen.

Growth in length is carried out by means of an apical cell, which is placed at the bottom of a pit or depression at the apex (*fig.* 792). The branching may be lateral or dichotomous.

The reproductive organs are variously situated, but always occur in peculiar depressions of the surface known as *conceptacles* (*fig.* 793, *l*). These are nearly globular cavities in the thallus which open to the surface by small pores or apertures known as *ostioles*. They are developed near the growing point. One or more cells cease to grow, and by the continued increase in size and number of those adjoining them a pit is formed which becomes ultimately the cavity of the conceptacle. The distribution of the sexual organs in the conceptacles varies in different species. In some, antheridia or oogonia arise in each; in others the same conceptacle may contain both.

The cells at the bottom of the conceptacle grow out into hairs, from some of which the sexual organs arise. The antheridia are formed in great numbers as the terminal cells of branches of these hairs (*fig.* 795). Each produces a number of bi-ciliated antherozoids, which are sometimes discharged into the conceptacle and make their way out through the ostiole. In other cases the antheridia are detached unruptured and escape from the conceptacle, the antherozoids being subsequently liberated.

The oogonia arise from two-celled hairs, of which the upper cell alone gives rise to the sexual organ, the lower one forming a stalk to it (*fig.* 794). Each oogonium develops usually eight oospheres, of generally spherical shape and having no cilia. The wall of the oogonium is composed of two layers, and when the oospheres are mature the outer layer bursts (*fig.* 796), and the inner one, covering the oospheres, is extruded. When this bursts later the latter are set free into the water. Fertilisation usually takes place outside the conceptacle, each oosphere becoming surrounded by a number of the ciliated antherozoids (*fig.* 797), one of which ultimately fuses with it, forming an oospore or zygote, which then secretes for itself a cellulose covering. The zygote generally germinates at once.

FIG. 792.

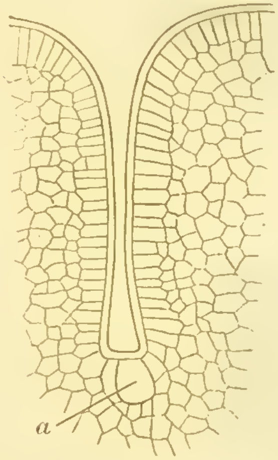


FIG. 793.

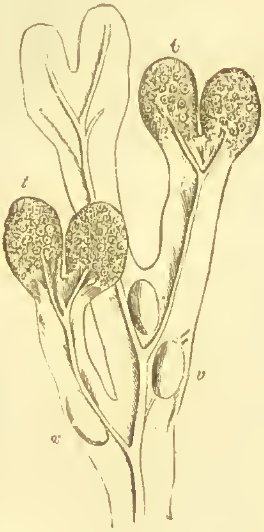


Fig. 792. Growing point of *Pelvetia*. *a*. Apical cell. After Kny. — *Fig.* 793. Thallus or thallome of the common Bladder Seaweed (*Fucus vesiculosus*). *t*, *t*. Groups of conceptacles. *v*, *v*. Bladders containing air.

Besides the sexual organs the conceptacles contain a number of barren hairs or paraphyses (*fig.* 794), which frequently are so numerous towards the top of the cavity as to protrude through the ostiole.

Certain conceptacles in some of the Fucaceæ do not give rise to sexual organs. These are generally known as *cryptostomata*.

FIG. 794.

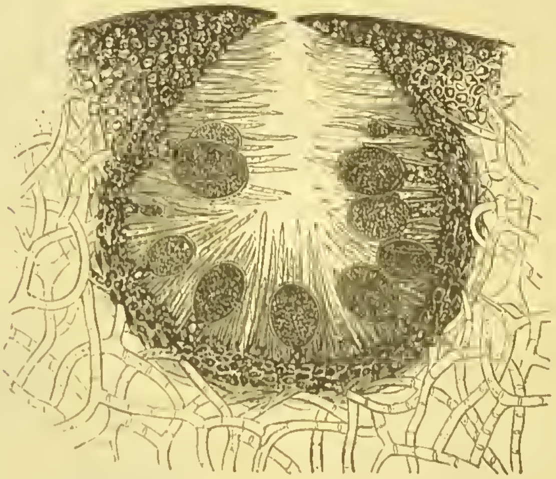


FIG. 795.

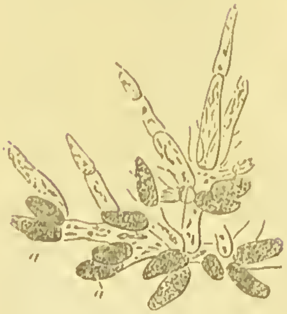


FIG. 796.

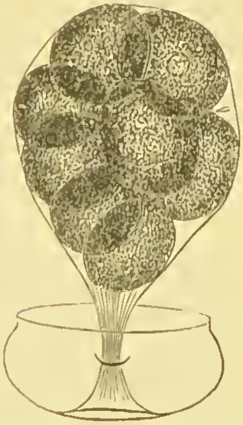


FIG. 797.

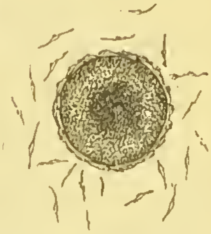


Fig. 794. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.——*Fig.* 795. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret.——*Fig.* 796. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.——*Fig.* 797. An oosphere without a cellulose coat surrounded by antherozoids.

These cavities contain only paraphyses, which are of greater length than those in the fertile conceptacles.

The LAMINARIACEÆ afford examples of the largest Algæ of the

Phæophyceæ; they show a good deal of variety of form, including long unbranched fronds terminating below in a thick stalk, as well as stems which bear a series of much and variously divided leaves. In some the stalk is so short and covered by rootlets, while the fronds are so long, that a single plant appears like a group of the unbranched forms. On the stalk, in some cases, gonidiophylls are developed in addition to the ordinary fronds, their development being acropetal. In some of the fronds midribs and subordinate veins occur, giving them a very leaf-like appearance. A few forms possess air-floats, something like those of the Fucaceæ. The stem or stalk terminates below in strong rootlets or haptera, which fasten the plant to a substratum of rock or stone.

The thallus shows still more complete histological differentiation than that of the Fucaceæ. The stalk contains epidermal cortical, and medullary tissue. The epidermal layer often becomes merismatic, though in many species the meristem is found in the peripheral part of the cortex. This merismatic layer is often very active and causes the stalk to become of considerable thickness. Like most merismatic layers, it forms new tissue on both its faces. The inner portion of the cortex in the stalk consists of a layer or cylinder of elongated cells whose walls are generally pitted. In *Macrocystis* it contains the peculiar sieve-tubes of which mention has already been made.

The central strand is something like that of the larger Fucaceæ, consisting of hypha-like filaments which anastomose copiously. This layer is continued upwards into the fronds.

The mucus passages already alluded to are only found in some of the Laminariaceæ. They are long tubes which branch and anastomose, forming a network in the tissue.

The growing point is sometimes apical, sometimes intercalary.

The reproductive organs are not produced in conceptacles but in sori, variously distributed over the fronds, but sometimes confined to definite gonidiophylls. Each sorus consists of a number of unilocular gonidangia, among which are found paraphyses. The gonidangia give rise to ciliated zoogonidia or zoospores. Some of the genera possess cryptostomata, which bear paraphyses as in the Fucaceæ.

The genus *Splachnidium* appears to occupy an intermediate position between Fucaceæ and Laminariaceæ. It is peculiar in that it bears gonidangia resembling those of the latter group.

which are developed, not in sori, but in conceptacles much like those of Fucus.

The Cutleriaceæ have a special interest as illustrating the evolution of sex in the Phæophyceæ. They possess two kinds of gametes which are both ciliated, the female, generally called an oosphere, being much larger than the male. The organs in which they arise are situated in sori on the surface of the thallus, and the gametes are set free by a lateral aperture in the wall. When they are liberated both kinds are freely motile; the female comes soonest to rest, and is fertilised by the fusion of an antherozoid with it.

The thallus is sometimes erect and sometimes prostrate. I grows by means of a cluster of hairs, the bases of which are merismatic. The rows of cells produced from each hair become united together laterally to form the tissue of the thallus.

The differentiation of the internal tissue is not so complete as in the other groups described. In *Cutleria* itself three systems can be seen; the epidermal layer, which contains chromoplastids in abundance, a cortical layer of clearer cells in which a little colouring matter is present, and an axial layer of larger cells, almost colourless. All the cells are parenchymatous, the pseudo-vessels of the former groups not being represented.

Asexual reproductive structures are met with in the Cutleriaceæ, which take the form of unilocular sporangia, each containing several zoospores. These resemble the gametes in being ciliated, but they are intermediate in size between the antherozoids and the oospheres. In the genus *Cutleria* they are borne upon the young plant produced from the germinating zygote. The form of this sporophyte differs considerably from that of the thallus which bears the sexual cells. There is thus in *Cutleria* an alternation of generations. In the other genus of the group, *Zanardinia*, the two forms are essentially similar.

The sexual organs are placed in sori, and originate in hair-like outgrowths of the thallus. The hairs bearing antheridia are often much branched, as in the case of Fucus. The sori contain paraphyses as well as sexual organs.

The Dictyotaceæ form a group somewhat resembling the Cutleriaceæ. The thallus is very varied in form, but is generally flattened. The branching is dichotomous, and usually arises from a longitudinal division of a small-celled apical meristem. A single apical cell is only known in the genus *Dictyota*. There is not much differentiation of internal tissue, an epidermis being, however, well marked off from a colourless internal mass. The sexual organs are antheridia and oogonia, and are grouped together in sori. The asexual ones are gonidangia, which occur in clusters or scattered over the surface of the thallus. The gonidia are non-ciliated and motionless. In some forms the reproductive cell, whether sexual or asexual, gives rise to a plant like the parent; in others a kind of filamentous body is developed, recalling the protonema of the Bryophyta, to be described later. The adult plant arises as an outgrowth from some of the cells of this filament.

The gonidia are often produced in groups of four in the gonidangia. In this point the Dictyotaceæ approach the group of the Rhodophyceæ.

The Syngeneticæ form a group which is in marked contrast with the rest of the Phæophyceæ. They are unicellular organisms, and resemble the Cyanophyceæ in forming colonies in consequence of the cells not separating after division, but remaining surrounded by their diffluent mucilaginous cell-walls. They have no sexual reproduction, but bear asexual gonidia, which are ciliated.

Sub-Class IV.—Rhodophyceæ.

This sub-class includes a large number of forms, nearly all of which are marine. They are found growing mixed with olive-green or brown forms at low-water mark and a little beyond, and in deeper water they occur almost alone. The fresh-water forms are few and belong only to two or three families. Some marine forms are parasitic on other red Algæ; others are epiphytic. Some members of this family have the thallus encrusted or impregnated with carbonate of lime, forming structures which superficially resemble the animal corals.

The morphological differentiation of the group is greatly in excess of their anatomical complexity. They are all multicellular, and generally form a much-branched thallus, which may be flattened and spreading, or may be filamentous. The segments of the shoot may in many cases be called leaves, and a root can usually be found.

The histological differentiation is much slighter than in the last group. The filamentous forms sometimes show nothing more than a single row of cells; sometimes there are several such rows, which may be covered by a kind of cortex composed of small cells. In these cases the rows of the filaments do not form a true tissue, but are bound together by a kind of intercellular substance, or are surrounded by a common gelatinous coating. Each row of cells grows by division of the terminal one, which is sometimes much larger than the others. There is no intercalary growth of the filament by division of any of the other cells, though lateral branches may arise from them. The successive cells of the row or rows constituting the thallus communicate with each other by a kind of rudimentary sieve-plate (*fig.* 798), though they can hardly be described as sieve-tubes.

FIG. 798.

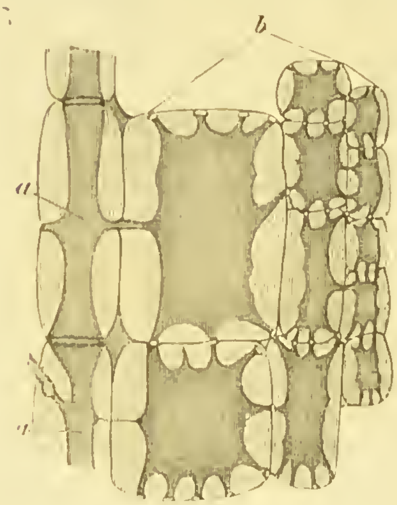


FIG. 799.

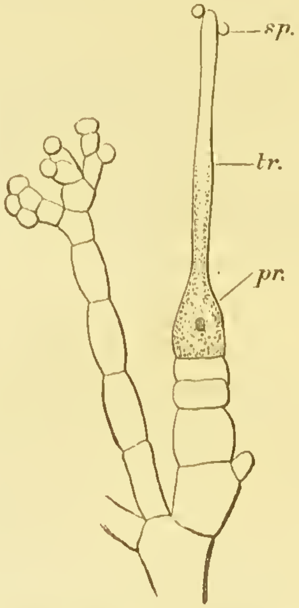


Fig. 798. Semi-diagrammatic longitudinal section of an old and stout portion of *Ceramium rubrum*, showing continuity between the protoplasmic contents of the axial or central cells, *a*, *a*, at their ends; and laterally with the cortical cells, *b*, by protoplasmic threads, and also that of the cortical cells *inter se* by threads radiating from the central mass in each cell. (After T. Hick.)

Fig. 799. Procarpium of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. *pr.* Carpogonium. The branch to the left bears a cluster of antheridia. (After Kny.)

The flattened forms usually grow at their margins, new cells arising from divisions in certain cells in definite positions there. The characteristic colouring matter is red, and is found in chromatophores in the cells. As in the last group, chlorophyll is present in addition to the phycoerythrine.

The group is characterised by great peculiarity in its methods of reproduction, which are both sexual and asexual.

The gametophyte bears sexual organs and gonidia, the latter sometimes occurring only in special forms. There is a sporophyte developed after fertilisation of the contents of the female organ, but this is always a very small structure, incapable of great development, and almost at once producing its spores.

The sexual organs are antheridia and carpogonia or procarpia. The antheridia are borne generally in clusters, which are often situated at the end of a filament (*fig.* 799), but which may be collected into various groups upon the surface when the thallus is flattened. Sometimes they are found in pits or depressions of the surface, something like the conceptacles of *Fucus*. Each antheridium produces externally a number of special cells in which the male gametes are produced singly. The gamete is a mass of protoplasm, which at first in most cases has no cell-wall, but which secretes one after its liberation from the mother-cell, usually just before it reaches the female organ. The term applied to the male gamete is *pollinoid* or *spermatium*; it differs from the antherozoids of the former group in not possessing cilia. The pollinoids are discharged from the antheridial cells by the latter opening at their apices.

Some botanists hold that the structure described above as an antheridium is really a cluster of them, and that the true antheridium is the special cell alluded to. On this hypothesis the antheridia are numerous and unicellular, and give rise each to a single pollinoid.

The female organ, or carpogonium, is peculiar in that it never produces an oosphere, but its contents remain undifferentiated. It is usually a cell with a somewhat swollen base and a long narrow pointed apex. The latter is called the *trichogyne* (*fig.* 799, *tr*), and is the part which is concerned in the act of fertilisation. The carpogonium proper is often the terminal cell of a short branch consisting of three or four modified cells which are sometimes sunk in the thallus. When the carpogonium is mature a pollinoid comes into contact with the trichogyne, which always projects above the surface of the thallus, even if the whole carpogonial branch is not exposed. The wall of the pollinoid and that of the trichogyne become absorbed at the point of contact, and the contents of the former pass into the cavity of the latter. The further stages of the process have not been observed, but as there is no differentiated oosphere it is probable that the nucleus of the pollinoid fuses with that of the carpogonial cell. The trichogyne becomes cut off from the rest of the carpogonium and withers away.

Fertilisation having been thus accomplished, the further development of the structure varies very greatly in different groups, leading in all ultimately to the production of a fruit-like structure which is known as a *cystocarp*, and which may probably be regarded as the sporophyte phase of the plant. It consists essentially of a cluster of *carposporangia*, variously arranged and often enclosed in a definite encasement of filaments or cells. There are five different types of formation. The first is seen in the NEMALIONACEÆ; here from the fertilised carpogonium filaments known as *gonimoblasts* grow out, often in dense clusters. The terminal cells of the filaments are the carposporangia, and each produces internally a single carpospore. The whole group constitutes the cystocarp (*fig.* 800), which is consequently not enclosed in any specially differentiated case. Sometimes the gonimoblasts arise from the upper part of the carpogonium, sometimes from its side. In some of the families the cystocarp is immersed in the tissue of the thallus. In the Gelideæ the cells of the gonimoblast become united here and there to certain cells of the thallus, from which it absorbs nourishment.

FIG. 800.

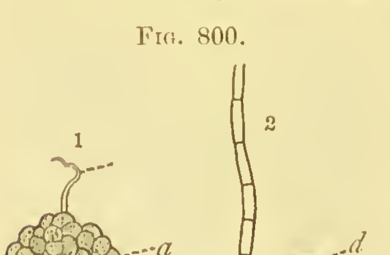


Fig. 800. 1. Cystocarp of *Nemalion.* *a.* Carposporangia.
2. Cystocarp of *Lejolisia.* *b.* Carposporangia. *c.* Wall of cystocarp. *d.* Carpospore escaping. After Kny.

The second type is furnished by the GIGARTINACEÆ; in this, besides the branches which carry the carpogonia, other special cells are produced on the thallus near them, generally in pairs. These cells are known as *auxiliary cells.* When the carpogonium has been fertilised it does not give rise at once to gonimoblasts, but puts out a short protuberance known as an *oöblastema filament.* This makes its way to an auxiliary cell, and the contents of the two fuse. The gonimoblasts arise from the resulting cell and branch in the interior of the thallus, the cystocarp being thus embedded in its substance. The fruit thus arises from the auxiliary cell rather than immediately from the carpogonium as in the Nemalionaceæ.

The third type, characteristic of the RHODOMENIACEÆ, is still more complex. The formation of the cystocarp is indirect as in the last case, the carpogonium conjugating with an auxiliary cell. A complex procarpium is formed, consisting of carpogonial branches and certain cells which ultimately give rise to the auxiliary cells. The latter are not developed till after the fertilisation of the carpogonium. When they are complete, conjugation takes place between an oöblastema filament from the carpogonium and either the auxiliary cell or a process growing out from it. In some cases the carpogonial and auxiliary cells coalesce without the intervention of either outgrowth. After the process of conjugation is accomplished, gonimoblasts grow out from the resulting cell and form a much-branched collection of filaments which generally protrude from the thallus. Each gives rise to a number of carposporangia. The thallus tissue sends out filaments which coalesce round the cystocarp, forming a protecting cell or case (*fig.* 800, *Lejolisia*). In some cases where the cystocarp is formed upon a slender leaf-like branch of the thallus the filaments proceed from near the cell which bears the carpogonial branch, and curling over the latter cover it in. The wall generally begins to be formed as soon as the carpogonium is fertilised. In some cases no protective coating is formed.

The most complicated type is met with in the CRYPTONEMIACEÆ. The fertilised carpogonium sends out a very long oöblastema filament which branches copiously, and consists of several cells. There are many auxiliary cells formed upon separate branches, and one oöblastema filament communicates with several of them, fertilising several in succession. From each of these gonimoblasts proceed; and these branch repeatedly, the cells of the branches forming carposporangia, each containing a single carpospore. The gonimoblasts ramify in the substance of the thallus, so that the fructification is internal, and surrounded by thallus tissue.

The CORALLINEÆ form a very special family of this group. Their thallus, which varies very much in form, is encrusted or impregnated with carbonate of lime, the coating covering every part except the reproductive organs. They bear curious cystocarps, which are really compound, and resemble the conceptacles of *Fucus*. In the hollow of the conceptacle, which opens apically, several carpogonia occur, each with its trichogyne. Other filaments only produce auxiliary cells. After a carpogonium has been fertilised it fuses with many of the auxiliary cells by means of a single oöblastema filament, and a single large cell is formed. The gonimoblasts, each of which bears a chain of carposporangia, arise in some numbers from the periphery of this cell. The cystocarp is surrounded by the wall of the conceptacle.

In the last type, that of the Bangiaceæ, the formation is simple and direct. as in the Nemalionaceæ. The carpogonial cells are very little specialised, and only differ from the ordinary cells of the thallus by being a little larger. They grow outwards and give rise to a very rudimentary trichogyne, which becomes fused with a pollinoid as in the other groups. The fertilised carpogonium does not put out a gonimoblast, but either becomes at once a carposporangium, or divides into a number of cells, each of which may be regarded as one. The cystocarp consists merely of the cluster of sporangia, no wall being formed.

The asexual cells of the gametophyte are usually produced in groups of four in a gonidangium.[a] They are variously arranged (*fig.* 801), sometimes being formed in tetrads, sometimes in rows, and sometimes being quadrants of a sphere. They may occur within the cortical region of the thallus, or may be produced upon special hair-like outgrowths. The gametophyte in which they occur is very frequently a potential one, and when they germinate each gives rise to another potential individual. There is thus a succession of potential gametophytes, before an individual appears which bears sexual organs. This kind of alternation of generations has already been alluded to as *homologous* alternation.

Fig. 801.

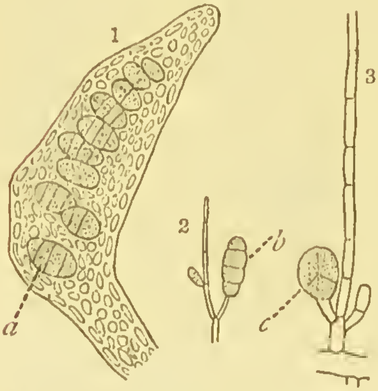


Fig. 801. Tetraspores of Rhodophyceæ. 1. *Plocamium.* 2. *Dudresnaya.* 3. *Lejolisia.* (2 and 3 after Kny.)

The gonidia differ from the carpospores in not being clothed with a cell-wall on their liberation. From their occurrence in groups of four they are usually termed tetraspores, or tetragonidia.

Sub-Class V.—Chlorophyceæ.

In many respects this group may be considered to approach most nearly the next great division of plants, the Bryophyta, as in the higher forms the oosphere is fertilised in the oogonium and not after extrusion from the plant. Though as a rule both anatomical and morphological differentiation are but slight, the peculiarities of sexual reproduction are thus more like those in the higher plants than are those of any of the other groups of Algæ.

The plants of this sub-class are, with few exceptions, very simple in the structure of their vegetative body. Like those of the last group, the predominant form is the gametophyte, the sporophyte being quite rudimentary, and consisting either of the fertilised female gamete, or of a small body resulting from a few divisions of the latter. They show several types of structure. Many are unicellular, and, in that case, of microscopic dimensions. Others form filaments, each made up of a single row of precisely similar cells, all of which are physiologically alike. A third type is seen in flat plates of cells, only a single cell in thickness; these may be very large and leaf-like, or they may form a very small group, microscopic in size. A group of this kind, in which the cells show no differentiation, or at most a difference between the ordinary cells of the thallus and the reproductive cells, is called a *cœnobium* or colony. Sometimes the cœnobium is spherical, and its cells are all furnished with cilia, giving it powers of locomotion. In a fourth type the thallus is cœnocytic—that is, there are no internal cell-walls formed between the constituent cells, so that the whole plant appears like a single large cell with many nuclei embedded in its protoplasm. The cœnocyte may be a filament, or a somewhat globular body with a branched base (*fig.* 803), or a branched structure, showing differentiation into stem and leaf and root. In some cases of cœnocytic structure the body is divided by transverse walls in several places, so that it may be regarded as composed of a number of cœnocytes. Lastly, the body may be cellular and differentiated into root and shoot, the latter bearing branches and leaves.

In habit the Chlorophyceæ vary but little. They are found in both salt and fresh water. Most forms are free; some are attached to a substratum. A few are endophytic, inhabiting cavities in other plants much as *Nostoc* does. They present hardly any histological differentiation, with the exception of the Characeæ, where the stem sometimes shows a rather complex structure, and curious reproductive bodies are produced.

The gametophyte may produce both asexual and sexual cells, and may propagate itself vegetatively by simple division or by the production of gemmæ. The sexual organs are in some cases very simple, any cell of a filament having the power to produce a number of bi-ciliated gametes, which are liberated by rupture of the cell-wall. These, after a period of activity, conjugate in pairs, the conjugating cells generally originating from two different cells or even two different filaments. The differentiation of sexuality in some of these is very slight, for if they fail to conjugate they can still germinate as if asexual cells. In another group, while apparently any cell of the filament can become a gametangium, the contents are not differentiated into ciliated free-swimming bodies, but the whole of the protoplasm undergoes a kind of rejuvenescence and forms a single gamete. In other forms definite antheridia and oogonia are produced, which furnish antherozoids and oospheres respectively. In each oogonium, as a rule, only a single oosphere is produced, and this is fertilised *in situ* by the entry of an antherozoid into the oogonium (*fig.* 804). This marks a striking advance upon the sexual process in the Phæophyceæ, where the oospheres are set free and fertilised outside in the water. It approaches to the condition in the next group, where more elaborate provision is made to bring the sexual cells together. In the cases of conjugation of the solitary gametes in a gametangium, the fusion of the cells always occurs within one of the cells or an outgrowth from it, the gametes never being set free.

Fig. 802.

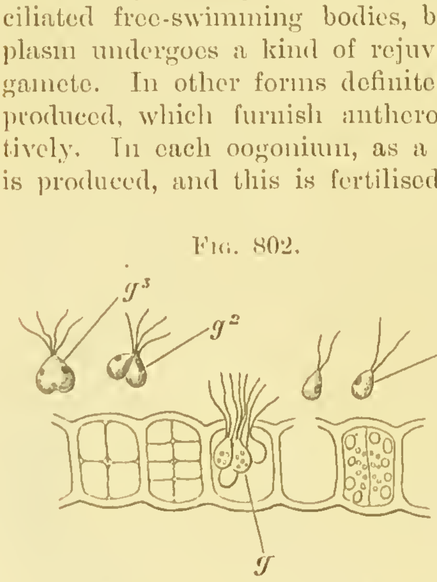


Fig. 802. Part of a filament of *Ulothrix* from which the gametes, g, are escaping. g^1. Free gamete. g^2, g^3. Gametes conjugating.

In the latter case parthenogenesis sometimes occurs, a gamete developing into a new filament without any process of conjugation. Such gametes are called *azygospores*.

In one exceptional case, *Sphæroplea*, several oospheres are formed in the oogonium, which is not a specially differentiated cell. Here, too, fertilisation takes place internally, antherozoids finding their way into the cell by an opening in the wall.

Asexual cells are produced by most, but not by all the members of this group. They are generally free-swimming cells, or in some cases cœnocytes, either ciliated all over their surface, or having a pair of cilia at one end, which is usually pointed, giving them a pear-shaped appearance. They are not produced in specially differentiated gonidangia; apparently any cell of the thallus can give rise to them.

The sub-class has been very variously subdivided, and at present it is difficult to give a very detailed classification. Several types of structure may be briefly described.

PROTOCOCCACEÆ.—These are the simplest of the sub-class; the plants consist of single cells or of colonies of cells united by a common mucilaginous cell-wall. They multiply by cell-division, or by formation of zoospores, or by the conjugation of two free-swimming gametes. In the latter case the zygote represents the sporophyte and gives rise to two zoospores on germination.

FIG. 803.

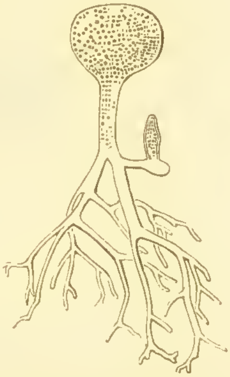


Fig. 803. Cœnocyte of *Botrydium granulatum.*

VOLVOCCACEÆ.—Of these the most remarkable plant is *Volvox* itself. It consists of a hollow sphere formed of a single layer of cells, each of which is furnished with a pair of cilia. By the movement of these the plant rotates rapidly and makes its way through the water. Some of the cells of the sphere produce a number of orange-coloured ciliated antherozoids; others represent oogonia, and each gives rise to a single oosphere. The latter is fertilised *in situ* and divides into a number of cells, which become arranged into a hollow sphere like the parent. Certain other cells of the colony, which may be taken to represent gonidia, can divide similarly *in situ*, and produce within their cell-wall a miniature *Volvox*. Several of these may often be seen in the interior of the hollow sphere of the parent, into which they are discharged from the gonidangial cell. They only escape on the death of the parent. Other genera of this group are *Pandorina* and *Eudorina*; the cœnobium of the former is a solid sphere, that of the latter a hollow one. Pandorina reproduces itself by gametes which are alike, Eudorina by antherozoids and oospheres. The zygote of *Pandorina* represents the sporophyte and produces zoospores. That of *Eudorina* is like that of *Volvox*. Other genera produce colonies or cœnobia which are flattened instead of spherical.

SIPHONEÆ.—These are the most remarkable forms of the group, the thallus consisting of a single cœnocyte, often of very large dimensions, or of a number of cœnocytes attached to each other, forming a filament. The largest members of this family belong to the genus *Caulerpa*, which in many cases simulates the different types of habit exhibited by terrestrial plants. The stem and leaves are nearly always well represented, and the root system is clearly differentiated. The internal cavity of the cœnocyte is crossed by interlacing strands or trabeculæ formed of a modification of cellulose, and springing from the outer wall of the structure. A form of much humbler type, but more familiar to us from its occurrence in fresh-water and in muddy places, is *Vaucheria* (*fig.* 804). The plants are filamentous cœnocytes, which branch irregularly or dichotomously. There is but little differentiation, but from some of the filaments curious root-like structures are developed for purposes of attachment. Other forms are *Acetabularia*, where there are stalks crowned by whorls of coherent leaves, and *Botrydium* (*fig.* 803), where a bladder-like head is continued downwards by a slender stalk to a much-branched root, all being a single cœnocyte. Forms composed of several cœnocytes united into a filamentous thallus are shown by the genera *Sphæroplea*, *Cladophora*, &c. The curious genus *Hydrodictyon* is sometimes referred to this group.

Fig. 804.

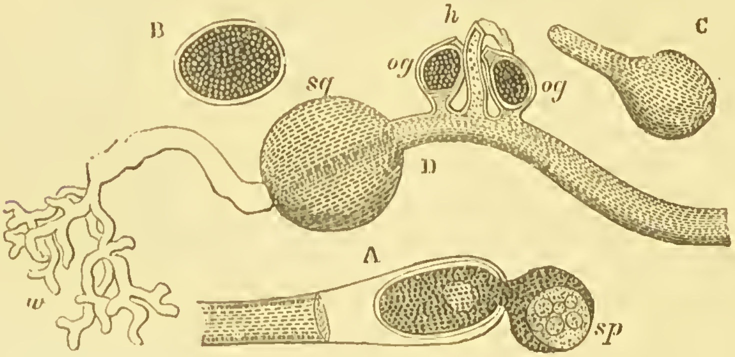


Fig. 804. A. *sp.* Newly formed zoocœnocyte or zoogonidium of *Vaucheria sessilis* escaping. B. The same at rest after having lost its cilia. C. First stage of germination. D. Filament of *Vaucheria sessilis* producing oogonia, *og*, *og*, and antheridium, *h*. *w*. Hyaline root-like process, forming a sort of mycelium. *sq*. Zoocœnocyte, which by germinating has formed the filament. After Sachs.

The reproductive processes of the group may be sexual or asexual. The sexual cells are usually all alike and are free-swimming ciliated gametes, which conjugate in pairs. Vaucheria is exceptional in producing antheridia and oogonia (*fig.* 804), which are developed in close proximity to each other from the surface of a filament. Each becomes shut off from the rest of the cœnocyte by a cell-wall. The antheridium gives rise to a number of antherozoids which are liberated by the rupture of the apex. The oogonium contains a single oosphere, and when it is mature it·opens at the apex, and a drop of mucilage is extruded. An antherozoid enters the oogonium and effects fertilisation. There is no sporophytic form, the zygote germinating to produce a new gametophyte.

In *Sphæroplea*, which is composed of several cœnocytes, any segment of the body may become an antheridium or an oogonium. There is not thus the differentiation of the organs seen in *Vaucheria*. The antheridia produce a large number of antherozoids, and the oogonia develop several oospheres in each. Fertilisation takes place by the entry of the antherozoids into the oogonia through openings in the walls of the latter. Unlike *Vaucheria*, this plant shows an alternation of generations, the oospore not producing at once a new *Sphæsoplea* plant, but giving rise to free-swimming zoospores, which form the new filament when they come to rest and germinate. The oospore thus represents the sporophyte.

Asexual reproduction is not common; when it takes place it is brought about by the formation of zoogonidia. These are generally motile and have a varying number of cilia. In *Vaucheria* (*fig.* 804), a single zoogonidium or *zoocœnocyte* is formed at the end of a filament, a portion of which becomes segmented off by a wall. The protoplasm of this portion undergoes rejuvenescence, and becomes ciliated all over, a pair of cilia being placed over each nucleus of the new cœnocyte. It escapes by rupture of the apex of the filament. In some forms the asexual gonidia are non-motile.

CONFERVOIDEÆ.—The forms included in this group are either unicellular, filamentous, or membranous; the filaments are sometimes branched, sometimes not, the membranous ones sometimes form flat plates, sometimes hollow or tubular expansions. The growth of the filaments is generally intercalary. They are always composed of cells and not of cœnocytes.

The processes of reproduction are both sexual and asexual. The origination of sexuality can be traced in some members of the group. In *Ulothrix*, which is a filamentous multicellular form, the contents of certain cells of the filament give rise to a large number of free-swimming ciliated cells, which indicate in their behaviour the beginning of sexual differentiation. They often conjugate in pairs (*fig.* 805), forming zygospores and thus indicating that they are essentially gametes. If they do not succeed in conjugating, they still can germinate; a fact which shows that they are much akin to ordinary zoogonidia.

FIG. 805.

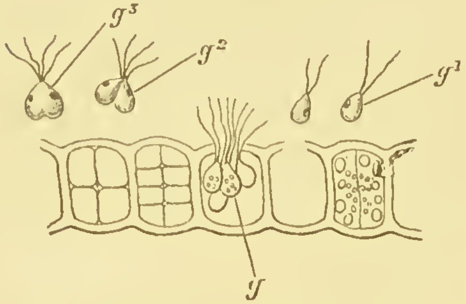


Fig. 805. Part of a filament of *Ulothrix* from which the gametes, *g*, are escaping. g^1. Free gamete. g^2, g^3. Gametes conjugating.

A further evolution of sexuality is found in the *Zygnemiæ*, to which *Spirogyra* belongs. Any cell of the filaments of the plant can become a gametangium. In the process of conjugation two filaments come to lie parallel with each other, and from the middle of each cell a lateral process grows out towards the other filament (*fig.* 806, *a a*). The opposite processes join and their walls fuse, forming a tube which stretches across between the two

FIG. 806.

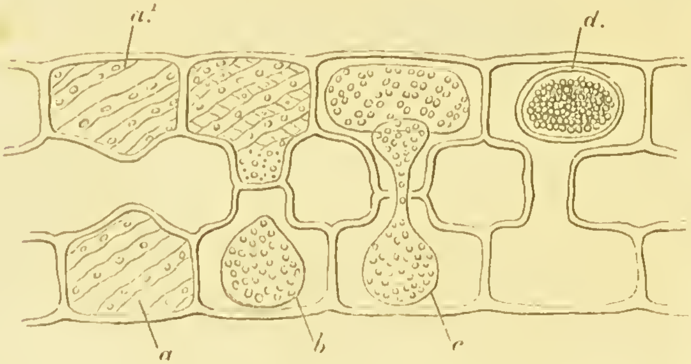


Fig. 806. Conjugation in *Spirogyra*. Two filaments are lying side by side, and from cells opposite to each other protuberances are growing out to meet, *a*, a^1. Each produces a gamete, *b*. When the protuberances have met and fused, one gamete passes over and unites with the other, *c*. *d*. Adult zygospore.

gametangia. The protoplasm of each undergoes rejuvenescence to form the gamete, and one of them passes over into or through the tube and fuses with the other gamete, which either enters the tube to meet the first or remains in its gametangium, where it is joined by the other. The first condition is found in *Zygogonium*, and as there is no difference between the gametes taking part, we cannot speak of difference of sex. In *Spirogyra* (*fig.* 806) the cell which passes over through the tube begins to be differentiated slightly sooner than the other and may be held to be the male one.

In *Œdogonium* sexuality is completely established, antherozoids and oospheres being produced. In some cases the whole contents of the antheridium forms a single antherozoid, which is ciliated.

Unicellular forms occur in this group in the family of the *Desmids*. These are cells of bright-green colour and usually peculiar shape. Their colouring matter is collected into curiously formed chloroplasts which may occur as bands stretching the whole length of the cell, and having pyrenoids embedded in them. They multiply chiefly by fission, as do the Diatoms, to which group they present certain resemblances. Occasionally two individuals conjugate

FIG. 807.

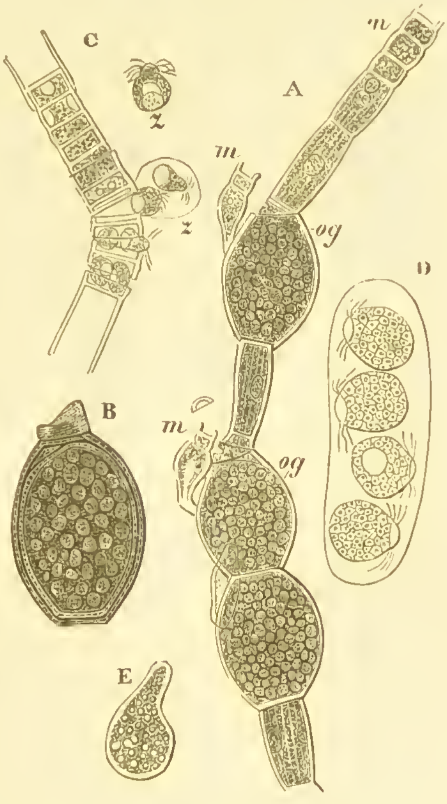


Fig. 807. A. Middle part of a sexual filament of *Œdogonium ciliatum*. *og*, *og*. Oogonia fertilised by the dwarf male plants, *m*, *m*, developed from androgonidia formed in the cells, *n*, at the upper part of the filament. B. Ripe zygote. C. Piece of male filament of a species of *Œdogonium*, showing production of antherozoids, *z*, *z*. D. The four zoospores resulting from a zygote. E. Zoospore at rest. After Pringsheim.

to form a zygospore, which germinates and produces two new plants.

The Zygnemiæ are, like the Desmids, furnished with peculiar chloroplastids. In *Spirogyra* these form a spiral band which winds round the cell; in *Zygnema* they form two stellate plates; other forms occur in other genera.

Œdogonium (*figs.* 807, 808) is noteworthy among the group on account of certain peculiarities of its reproduction. The ordinary filament produces a number of oogonia along its length, the cells swelling and becoming ovoid. Each produces a single oosphere. The antheridia may be on the same filament as the oogonia or on a different one. A cell of such filament divides transversely several times, and each cell so formed becomes an antheridium, giving rise either to a single antherozoid or dividing into two to form two mother-cells, each of which produces one. The oogonium admits the antherozoid usually by a perforation of the wall. Sometimes no antheridia are formed directly on the parent filament. Instead, special cells produced in the same way as antheridia set free their contents in the form of a ciliated cell known as an *androgonidium*. It is much like an antherozoid, but differs from the latter in its behaviour. It becomes attached to the wall of an oogonium and germinates, forming a very small plant, of three or four cells, known as a *dwarf male* (*fig.* 807, A, *m*), the upper cells of which are antheridia, and produce each a single antherozoid. When the oosphere is fertilised it clothes itself by a cell-wall, and the zygote so formed in due time germinates and produces four zoospores (*fig.* 807, D). It thus represents the sporophyte.

FIG. 808.

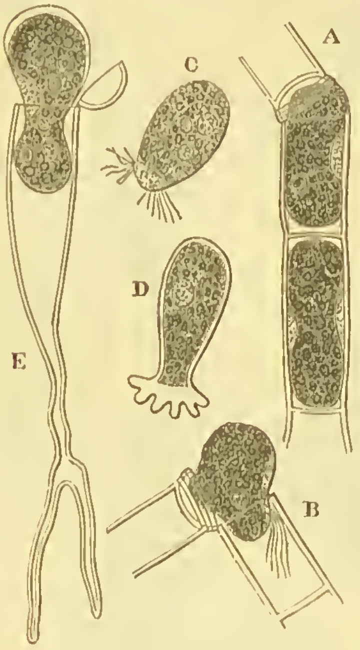


Fig. 808. A, B. Escape of the zoogonidia of an *Œdogonium*. C. One in free motion. D. The same after it has become fixed, and has formed the attaching disc. E. Escape of the whole protoplasm of a germ-plant of *Œdogonium* in the form of a zoogonidium. After Pringsheim.

Coleochæte is a form which in some respects approaches the red seaweeds. Its thallus is composed of much-branched filaments forming a tufted mass which grows apically or marginally. The cells in some cases bear peculiar sheathing hairs. The plant bears antheridia and oogonia, each of the latter bearing a trichogyne except in a few species. The antherozoid enters the oogonium by an opening in the trichogyne and fertilises the oosphere.

The result of the fusion is the production of a more elaborate sporophyte than in any other member of the Chlorophyceæ. The oosphere secretes a cell-wall round itself, and the oogonium in which it lies becomes surrounded by a kind of cellular covering derived from the cells of the thallus near it. It thus forms a kind of fructification which becomes detached from the parent. Later the zygote germinates, rupturing its coating; it only produces a few cells, each of which gives rise to a single zoospore.

The asexual reproductive cells produced by the Confervoideæ are zoogonidia or zoospores, as they are produced on the gametophyte or the sporophyte respectively. They are variously ciliated, and always on germination produce a gametophyte (*fig.* 808). The process of asexual reproduction is not found in the Desmids nor in the Zygnemiæ.

The last type of structure is found in the CHARACEÆ, represented most familiarly by the two genera *Chara* and *Nitella*. In some respects these approach nearest in structure to the Bryophytes; among the Chlorophyceæ they are distinguished by their relatively great degree of both morphological and anatomical differentiation and by the complex structure of their reproductive organs.

Chara exhibits a long slender stem, bearing whorls of leaves and branches, and consequently divided into nodes and internodes. The branches are developed in the axils of the leaves. The lower portion of the stem gives rise to a number of adventitious roots, which are filamentous and multicellular.

The growth of root, stem, and leaf is apical; in the stem and branches it is carried on by an apical cell.

The nodes and internodes differ in structure; in the latter the central core is formed by a single very elongated cell, which in the older parts contains several nuclei. It is not a cœnocyte, the nuclei being derived from the fragmentation of the original nucleus. This cell is covered in by a cortex consisting of a number of rows of cells which spring from the nodes above and below and accompany the internodal cell in its elongation. The nodes are made up of a number of small cells, from the external ones of which the branches and leaves arise.

FIG. 809.

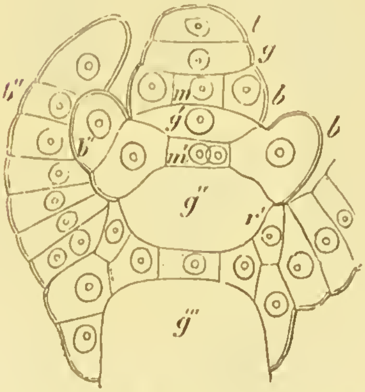


Fig. 809. Longitudinal section through the apical region of three primary shoots of *Chara fragilis*. *t*. Apical cell, in which segments are formed by septa, each segment being further divided by a curved septum into a lower cell not further divisible, which develops into an internode, g, g', g'', g''', and an upper cell which produces a node, m, m', and the leaves, b, b', b'', b'', which also undergo segmentation. After Sachs.

The growing point of the stem of *Chara* is seen in *fig.* 809. When it divides it cuts off a segment by a transverse wall; this cell is again divided similarly into two, of which the upper becomes a nodal and the lower an internodal cell. The nodal cell divides by vertical walls, while the internodal one only elongates. The peripheral cells of the node grow upwards and downwards to help to form the cortex of the internode above and below it. The apical cell of the leaf is similar to that of the stem, but it only keeps its activity for a short time. The apical cell of the root is not differentiated.

The reproductive organs are antheridia and oogonia, and are produced at the nodes of the stem. The antheridium is a shortly-stalked globular body, sometimes called a *globule* (*fig.* 810, A, *a*). Its case consists of eight cells with curious thickenings upon their surfaces. The top cell of the stalk projects into the interior of the antheridium between the bases of the lower cells of the case. Each of the eight wall-cells, known as *shields*, bears a long cell projecting into the interior, which is termed a *manubrium*; this is crowned by a smaller globular cell, the *capitulum*, and this in turn gives rise to six *secondary capitula*. Springing from each of these are two long filaments (*fig.* 812), divided into a large number of cells, each of which gives rise to a single antherozoid. The antherozoids are twisted masses of protoplasm, bearing two cilia at their anterior ends.

The oogonium is also stalked, the central cell being surrounded by filaments which arising beneath it from the node coil spirally round it (*fig.* 810, A, *s*). Each filament cuts off a small cell at its apex, so that the oogonium is covered in by a kind of neck or crown consisting of small cells. There are usually five of these. When the oogonium is mature these cells separate from each other, leaving a small channel through which the antherozoid can make its way.

Fig. 810.

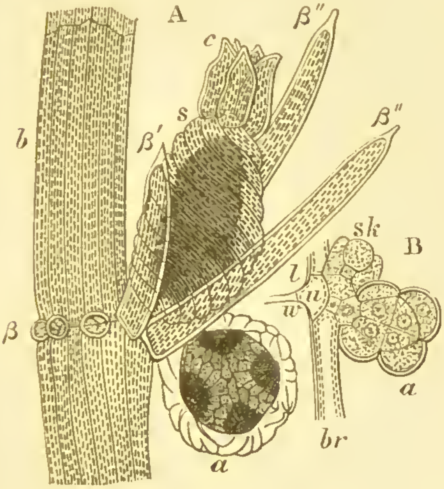


Fig. 811.

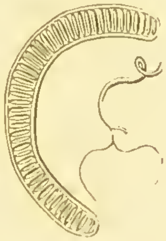


Fig. 812.

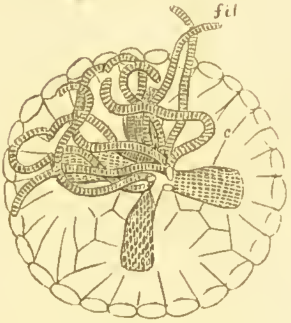


Fig. 813.

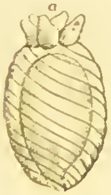


Fig. 814.

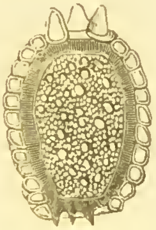


Fig. 810. A. Portion of the axis of *Chara fragilis.* *s.* Nucule or oogonium. *a.* Globule or antheridium. *b.* Internode. *c.* Crown or corona of nucule. β. Abortive leaves. β′, β″, β″. Sterile leaflets. B. *sk.* Nucule, and *a*, globule, both in an early stage of development. *w.* Nodal cell of leaf. *u.* Union cell between t and basal node of globule. *l.* Cavity of internode of leaf. *br.* Cells of leaf covered with cortex. After Sachs.——*Fig.* 811. A portion of a filament, *fil*, of *fig.* 812, in the cells of which the antherozoids are developed; with a 2-ciliated *antherozoid* by its side.——*Fig.* 812. A globule cut in half to show the oblong cells or manubria, *c*, and the septate filaments, *fil.* After Henfrey.——*Fig.* 813. Nucule or archegonium of *Chara.* *a.* Apices of the spirally wound cells.——*Fig.* 814. Vertical section of a nucule.

The oosphere is solitary in the oogonium, though as it becomes ready for fertilisation it cuts off one or two small cells from near its base. These cells are separated from it by cell-walls, but the oosphere itself remains naked.

The oogonium does not open, but the antherozoid makes its way through the cell-wall, which undergoes a sort of mucilaginous degeneration. The fertilised oosphere after fusion with it becomes an zygote with a very thick wall.

The germination of the zygote is peculiar; a transverse wall is formed near the apex and a small cell is so separated from the rest. The latter part of the zygote takes no part in the further development, but remains as a store of nutriment for the young embryo. The small cell divides into two, and from one of these the new shoot is developed, the primary root arising from the other. A small *pro-embryo* is thus produced which bears a single whorl of leaves and a few adventitious roots. The *Chara* plant arises as a bud upon this, its apical cell being differentiated among the whorl of leaves (*fig.* 815, *g*).

In the genus *Nitella* the stem is much more slender than in *Chara*, and it is not furnished with a cortex.

There are no asexual cells produced, but vegetative propagation is sometimes brought about. Certain branches of peculiar form may become detached from the parent and grow into new plants; or gemmæ may be developed upon the underground nodes.

Not producing any asexual cells, *Chara* does not exhibit any alternation of generations. The plant is the gametophyte.

FIG. 815.

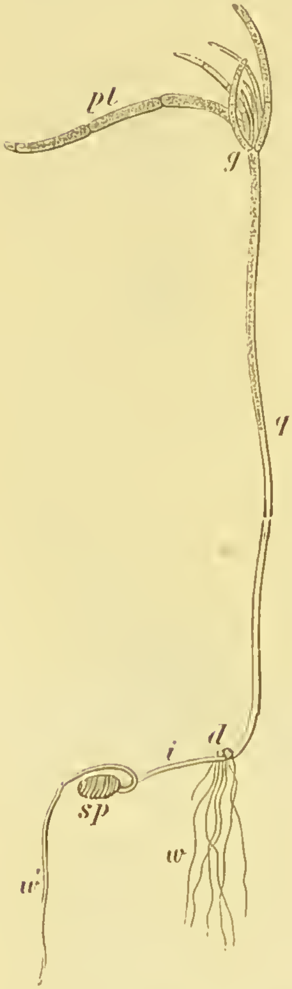


Fig. 815. Pro-embryo of *Chara fragilis*. *sp.* Germinating spore. *i*, *d*, *q*, *pl*. The pro-embryo. At *d* are the rhizoids, *w*. *w'*. Primary root. *g*. First leaves of the second generation, or *Chara* proper. After Pringsheim.

Class II.—FUNGI.

This class of Thallophytes differs from the preceding one especially by the absence of chlorophyll from the tissues of the plants which it comprises. In other respects there is a great similarity between the two groups. The absence of chlorophyll, however, makes such a material difference to the mode of nutrition, and leads ultimately to such great differences in degree of development, that they are properly separated into two distinct classes. The fungi cannot appropriate the CO_2 of the atmosphere, and are therefore compelled to obtain their carbonaceous food from somewhat complex compounds, which have, however, a fairly wide distribution. Some fungi obtain them from other living organisms, both animals and vegetables, on which they prey, their tissues entering into the living substance of their hosts and absorbing therefrom the food-stuffs they need. These are called *parasites.* Others grow upon decaying organic matter, either in the soil or elsewhere; these are known as *saprophytes.* Yet a third class exists, whose members live in intimate relationship with living green plants, the two forming together a complex organism, partly chlorophyllaceous, partly fungal, the two constituents playing each its own part in the nutrition of the whole. Such a mode of life is called *symbiosis*; it differs from parasitism in that the fungus does not in any way injure the green plant with which it is in such close relationship. The best examples of symbiosis may be found in the next class, the Lichens, where an alga and a fungus live together. In this it is illustrated by the mycorhiza found on the roots of many of our forest trees.

In their life history the fungi show an alternation of generations, but not at all a regular one. Many species have both gametophyte and sporophyte phases, but these rarely if ever alternate with constancy. The gametophyte is always the larger and most important form, the sporophyte being sometimes represented only by the oospore or zygospore, sometimes by a small *promycelium* developed from it, sometimes by a kind of fructification recalling the cystocarp of the red Algæ. The gametophyte usually bears gonidia in addition to the gametes; indeed many gametophytes are only potential ones, usually producing gonidia alone. Many generations of these may occur in succession before an actual one with sexual organs is formed. Hence we often get, as in the Algæ, in the life history an alternation, generally very irregular, of potential with actual gametophytes, in addition to the alternation of sporophyte with gametophyte, which is also very irregular. The former has been called *homologous*, the latter *antithetic* alternation.

Again, some of the gametophytes have lost the power of producing sexual cells at all, probably in consequence of the degeneration of structure that has accompanied the parasitic or saprophytic modes of nutrition. They thus never produce any reproductive cells but gonidia, and can only be distinguished as gametophytes by a careful study of their homologies.

FIG. 816.

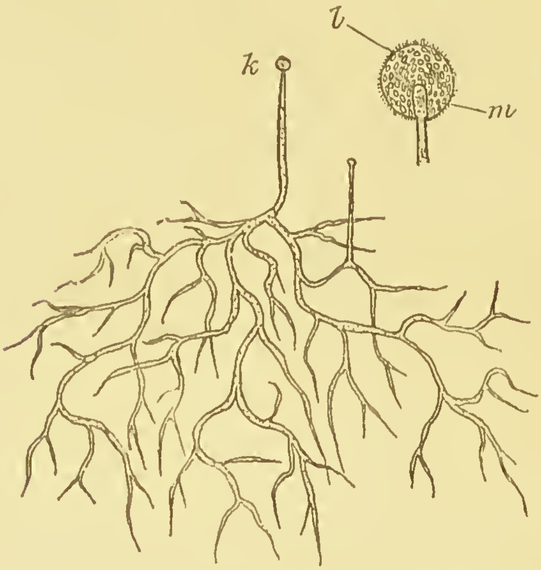


Fig. 816. Cœnocyte of *Mucor Mucedo*, bearing a gonidangium, *k*. This is more highly magnified in the figure to the right. *m*. Columella. *l*. Gonidia.

Polymorphy is very widespread among the Fungi. As we have seen, the plant body is in most cases the gametophyte. It may be unicellular, consisting of separate cells of various shapes, rounded, oval, or irregular. It may be a cœnocyte (*fig.* 816), when the appearance it presents is that of a number of white interlacing filaments, or *hyphæ*, with no separating transverse walls, but with many nuclei embedded in the protoplasm which lines them. This network of hyphæ, which is characteristic of most fungi, is known as the *mycelium*. Often the mycelium is septated into segments, each of which is a small cœnocyte. In one group, the Myxomycetes, the plant body is a *plasmodium* (*fig.* 817), consisting of an aggregation of cells which possess no cell-walls, but are capable of amœboid movements. The plasmodium is of course a form of cœnocyte.

Fig. 817.

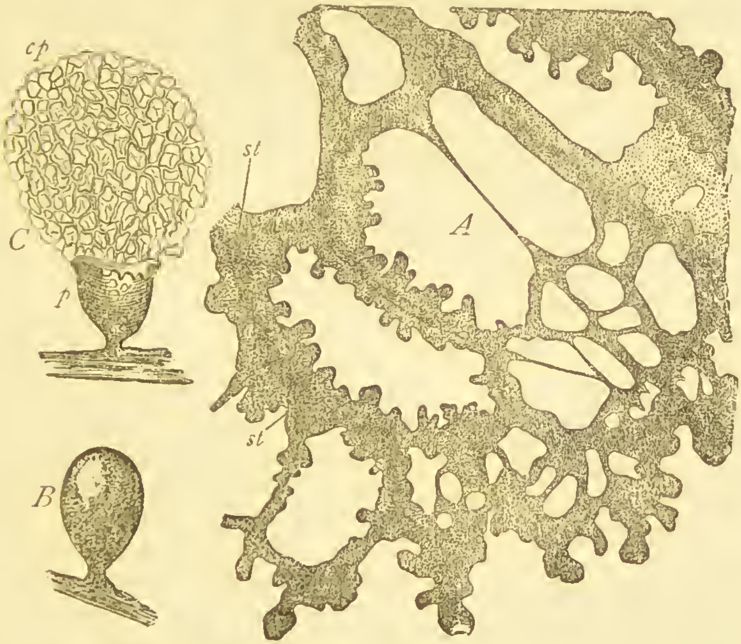


Fig. 817. *A*. Plasmodium of a Myxomycete (×300). *B*. A fructification still closed. *C*. After rupture of the wall *p*, and extension of the capillitium, *cp*. ×20. (After De Bary.)

The degree of differentiation which is shown by the plant body varies a good deal. Some are always single cells, others by division of these form strings or chains of cells; others form the mycelia already noticed, and in many cases their hyphæ, combining in various ways as they grow, produce large masses of tissue.

In nearly all cases but the first two, the body can be seen to be composed of parts which may be called root and shoot. In many the former is much the greater in extent and forms the larger part of the mycelium, being buried in the substratum on which the fungus is growing. In such cases the shoot is composed of a few hyphæ, bearing the reproductive organs. In other cases the shoot is large and bulky. In some parasitic forms the root hyphæ take the form of *haustoria*, or sucking organs, which penetrate into the cells of the host plant (*fig.* 818), the rest of the mycelium being found only between the latter. Sometimes, instead of forming a feltwork of mycelium, the root hyphæ are gathered into bundles. The shoot, especially when bulky, is of curious and varied form and never bears anything that can be called a leaf.

Corresponding with this rudimentary morphological differentiation, the anatomical structure is very simple. The long chains of cells are produced by ordinary cell-division; the elongated hyphæ grow at their apices; in the masses of tissue of the more bulky forms a transverse section shows the appearance of a kind of parenchymatous tissue. It is not a true parenchyma, however, being composed of hyphæ which run side by side, cohering together. The outer layers of such a mass form a kind of cortex, which is more compact than the inner parts. Occasionally some of the hyphæ are modified to form a system of laticiferous tissue, and a kind of gland is formed in some other species. These forms are found generally in the most complex group, the Basidiomycetes.

FIG. 818.

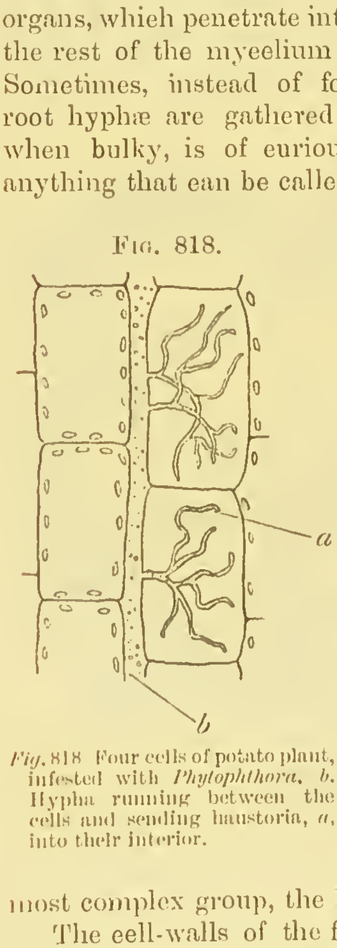


Fig. 818. Four cells of potato plant, infested with *Phytophthora*. *b*. Hypha running between the cells and sending haustoria, *a*, into their interior.

The cell-walls of the fungi are composed of a modification of cellulose, characterised by not turning blue when treated with iodine and sulphuric acid. This modification, known as *fungus cellulose*, has recently been shown to resemble in some respects the *chitin* found in some animal organisms.

The reproductive structures found in the fungi are very varied. Sexual reproduction is represented in several of the groups, but in others it is unknown, the gametophytes being always potential and not actual. In many a somewhat elaborate sexual apparatus is formed, but it is doubtful how far actual fusion of the gametes takes place.

The gametes may be alike. In this case they are never set free from the gametangia, but the walls of the latter coalesce and fusion takes place inside the structure so formed, a zygospore being the result (*fig.* 819). These isogamous fungi form the group of the Zygomycetes.

In other cases both male and female gametes are found. The female is usually an oosphere, contained either singly or in numbers inside a structure that may be called an oogonium (*fig.* 820). In this case the male usually consists of a mass of naked protoplasm, which occurs in a special branch of one of the hyphæ, in close proximity to the oogonium. This branch is known as a *pollinodium* (*fig.* 820, *an*). In another section the male gametes are differentiated and are set free. They are small rounded cells, clothed with a cell-wall, and known as *spermatia*. They are produced by abstriction from the apex of a special filament, the *sterigma*, a number of these being developed in a special receptacle, the *spermogonium*. The female organ, which is known as an *archicarp* (*fig.* 783), contains no differentiated female cell, and corresponds to the procarpium of the Rhodophyceæ. This sometimes has a *trichogyne*, as in the latter group.

Fig. 819.

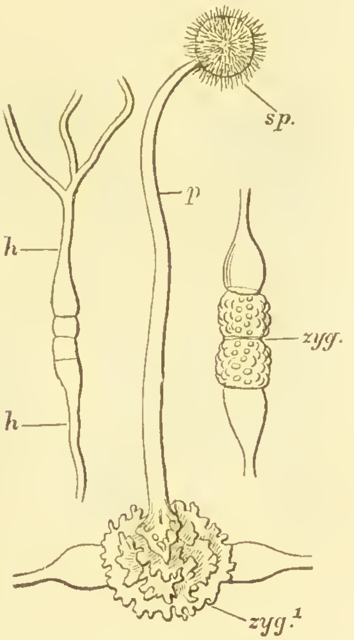


Fig. 819. Conjugation in *Mucor Mucedo*. *h*, *h*. Two hyphæ which have come into contact at their apices, and each has cut off from itself a cell. *zyg.* Zygospore resulting from the fusion of these cells. *zyg*¹. Adult zygospore after germination. *p*. Promycelium bearing a sporangium, *sp*.

In some forms which bear an archicarp the male cell is not differentiated either, but is much like the gamete of the group last mentioned, being produced by a hypha close to the archicarp. The product of fertilisation in the last two cases is known as an *ascocarp*, and is the sporophyte of the plant.

The spores or gonidia of fungi are borne in great numbers, and receive different names according to the organs in or on which they are produced. The sporophyte rarely occurring, it follows that they generally arise upon the gametophyte and are gonidia. In most cases they are small rounded bodies, each with its cell-wall. They may be produced singly in a cell, as in the Schizomycetes, or in groups of four or eight, as in the Ascomycetes, In most Phycomycetes they are produced in great numbers in globular or club-shaped gonidangia (*fig.* 822) borne upon special aerial hyphæ, termed *gonidiophores.* In other cases the gonidia are never in a gonidangium, but are produced from special hyphæ by a process of abstriction or budding, leading to the formation of strings of them, called *stylogonidia* (*fig.* 823). Usually each ultimately becomes free. In one group, the Uredineæ, they remain together, in number two or more (*fig.* 824), each of which can germinate while associated with the others. These are sometimes looked upon as compound gonidia, though each one is actually independent. This form is known as a *teleutogonidium.* There is some doubt as to whether the

FIG. 820.

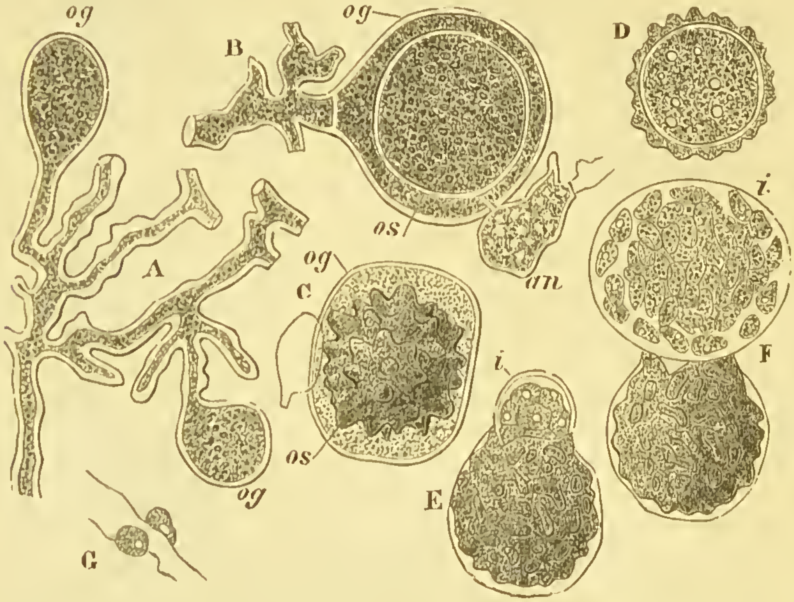


Fig. 820. A. Branched mycelium of *Cystopus* with young oogonia, *og*, *og*, B. Portion of mycelium bearing oogonium, *og*, with the oosphere, *os*; and antheridium or pollinodium, *an*. C. Mature oogonium, with *os*, the oospore or zygote. D. Mature oospore. E, F. Formation of swarm-spores or zoospores, G, from the oospores. *i*, *i*. Protruded endospore. After De Bary.

bodies described above as spermatia are not a form of the stylogonidia, and not sexual cells at all. In some cases they have been found to be capable of germination, producing a mycelium without any sexual fusion.

In a few families, such as the Saprolegnias, the gonidia are not clothed with a cell-wall, but are ciliated free-swimming bodies. They are produced in great numbers inside special terminal gonidangia (*fig.* 825).

FIG. 821.

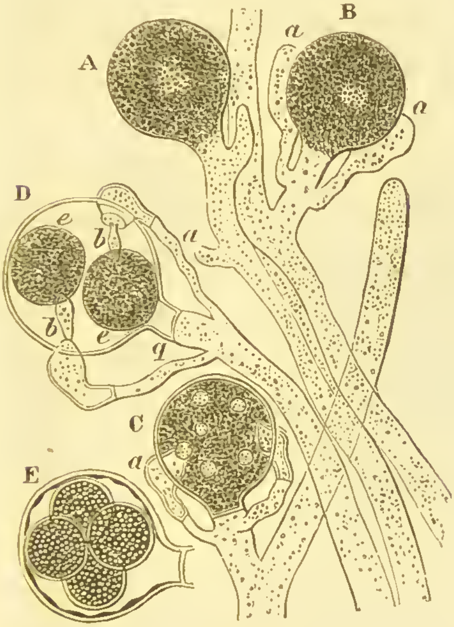


FIG. 822.

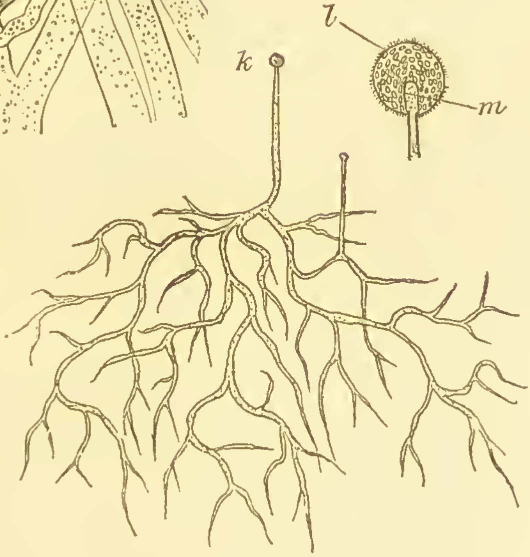


Fig. 821. Oogonia and antheridia of *Achlya lignicola.* The letters A to E indicate the course of development. The protoplasm of a cell or branch of a cell collects into a globular form A, B, and by the formation of a septum, D *q*, becomes an independent cell (the oogonium). The protoplasm then breaks up into two or more parts, D, *e*, *e* (oospheres), which quickly become spherical, as seen in D, secrete a cell-wall E, and become oospores. After Sachs.—*Fig.* 822. Cœnocyte of *Mucor Mucedo* bearing a gonidangium, *k*. This is more highly magnified in the fig. to the right. *m*. Columella. *l*. Gonidia.

The gonidangia may be produced singly or in groups. In the latter case the gonidiophores which bear them may be collected into special receptacles which are known as *pycnidia*.

Besides these sexual and asexual modes of reproduction, vegetative reproduction very commonly occurs. In forms such as Bacteria and yeast it is much the most general method, and consists only of ordinary cell-divisions, the daughter cells at once separating from the one which gives rise to them. Sometimes in yeast this separation does not at once take place, with the result that chains of cells are produced (*fig.* 826).

Fig. 823.

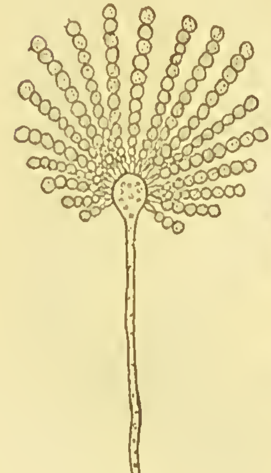


Fig. 824.

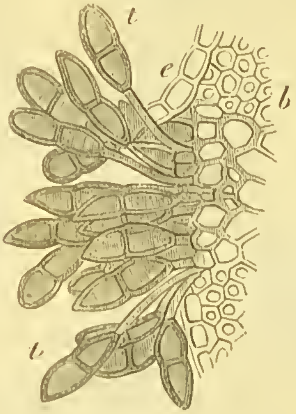


Fig. 825.

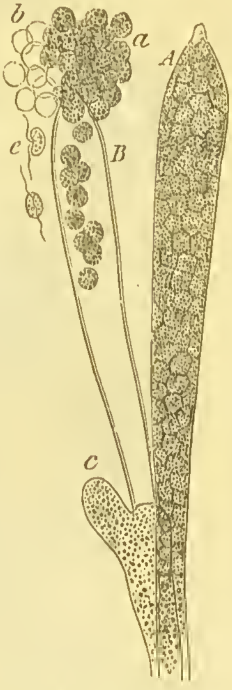


Fig. 826.

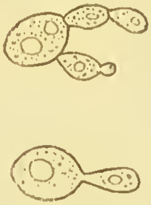


Fig. 823. Stylogonidia of *Eurotium*, formed by repeated abstriction from the basal cell. After Dodel-Port.—*Fig.* 824. Telentogonidia of *Puccinia graminis* bursting through epidermis of straw. After Dodel-Port.—*Fig.* 825. Two gonidangia of *Achlya*. A. Closed. B. Ruptured, and allowing the zoogonidia *a* to escape. *b*. Mother cells of the latter after escape of *c*, the zoogonidia, from them.—*Fig.* 826. Two yeast cells budding.

In other cases a hypha divides by the formation of transverse septa into a number of cells, each of which becomes rounded off, and the chain breaks up into single cells which are capable of immediate germination. They are often called *oidium* cells. More complex forms are the bodies known as *sclerotia*, which are composed of a mass of hyphæ closely felted together and covered by a pseudo-cortex. These separate from the mycelium which gives rise to them, and remain dormant for a longer or shorter period, ultimately putting out hyphæ like those of the original mycelium.

The fungi have been classified in various ways by different writers. The system which is now usually adopted divides them into six groups as under:—

1. Schizomycetes, including those bodies commonly spoken of as microbes, or bacteria. They are sometimes unicellular, sometimes filamentous and composed of chains of cells. They have no sexual reproduction.
2. Myxomycetes. The body of the fungus is a plasmodium or aggregation of amœboid cells with no cell-wall. They produce gonidia, but have no sexual reproduction.
3. Phycomycetes. These have usually a mycelium composed of a much-branched cœnocyte with no septa. They are often erroneously described as unicellular, a condition which, however, does occur in some cases. They reproduce sexually and asexually, zoospores and ordinary non-motile gonidia occurring in different orders. The sexual reproduction is a process of conjugation or fertilisation, leading to the recognition of two groups accordingly, the Zygomycetes and the Oömycetes. In the former the zygote is a zygospore, in the latter an oospore.
4. Ascomycetes. The cœnocytic structure is found in this group also, but the whole plant is usually not a single cœnocyte, but incompletely septated, forming a number of them. The female organ is a carpogonium, containing no differentiated gamete; the sporophyte is inconspicuous, but represented by the so-called fructification.
5. Æcidiomycetes. The mycelium has the same structure as in the last group. There is no sexual reproduction known. Several kinds of gonidium are borne. There is an elaborate structure produced, called an *æcidium*, which has been thought to represent the sporophyte, but the homologies are doubtful.
6. Basidiomycetes. The mycelium is much like those of the last two groups. No sexual reproduction is known. The mycelium produces a massive structure, on certain parts of which the gonidia are produced by abstriction from special cells, known as *basidia*.

Sub-Class I.—SCHIZOMYCETES.

The members of this group are very small, and almost structureless. The unicellular forms have various shapes, some being spherical (Micrococcus), some more elongated or rod-shaped (Bacterium), some forming a spiral (Spirillum). The multicellular forms are filaments, branched or unbranched, or small masses of cells. They are extremely polymorphic, one organism passing through several forms in its life history. Some are furnished with cilia, by which they move rapidly in the medium in which they live (*fig.* 827).

The cells are of a very simple structure, consisting of a cell-wall enveloping a mass of protoplasm. In this is found a body capable of staining more deeply than the rest of the cell-contents, and hence bearing some resemblance to a nucleus. The protoplasm often contains deeply staining granules, sometimes regularly disposed round the cell. The true nature of the staining material is, however, not yet accurately ascertained. Many of these cells contain various pigments.

FIG. 827.

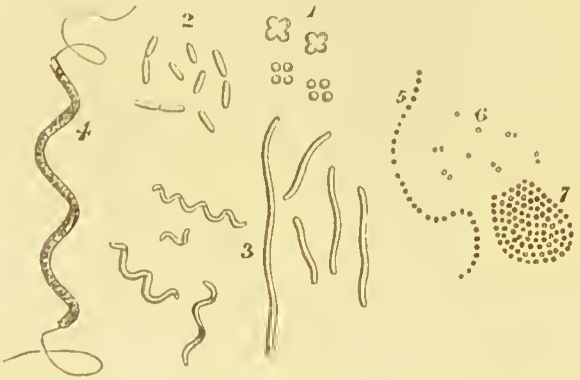


Fig. 827.
1. Sarcinæ.
2. Bacteria.
3. Spirilla.
4. Spirillum, showing flagellæ.
5. 6. 7. Micrococci in strings, singly and in groups. After Cohn and Sachs. (Very highly magnified.)

In the course of their life history, most of the Schizomycetes become embedded in a jelly-like substance which holds great numbers of them together. This is known as the *zooglœa* stage. The zooglœa may form a membrane or scum on the surface of the liquid in which the organism is living, or may occur in the shape of masses of various forms.

The reproductive processes are either vegetative or asexual. In the former case the multiplication takes place with enormous rapidity by ordinary cell-division. In the second case gonidia are formed, one in a cell, by a process of rejuvenescence. A filament may thus give rise to a chain of gonidia, which ultimately become separate by the degeneration of the original cell-wall. The gonidia have their own proper coats, which are much thicker and more resistent than the ordinary cell-wall. The zooglœa stage is generally the one in which the plant forms its gonidia.

It is to these organisms chiefly that the processes of fermentation and putrefaction are due, though other fungi take part in similar phenomena.

Sub-Class II.—Myxomycetes.

This curious group is distinguished by the fact that, except at a particular time in its life, it possesses no cell-walls. Originating from gonidia, the contents of the gonidium escape as a naked mass of protoplasm, which in some forms is capable of active movement by means of a cilium, and in others can only creep about slowly, by means of protrusions which it can put out from its substance. These are called *pseudopodia*. In the first case, the freely motile body passes over later into this stage, so that

Fig. 828.

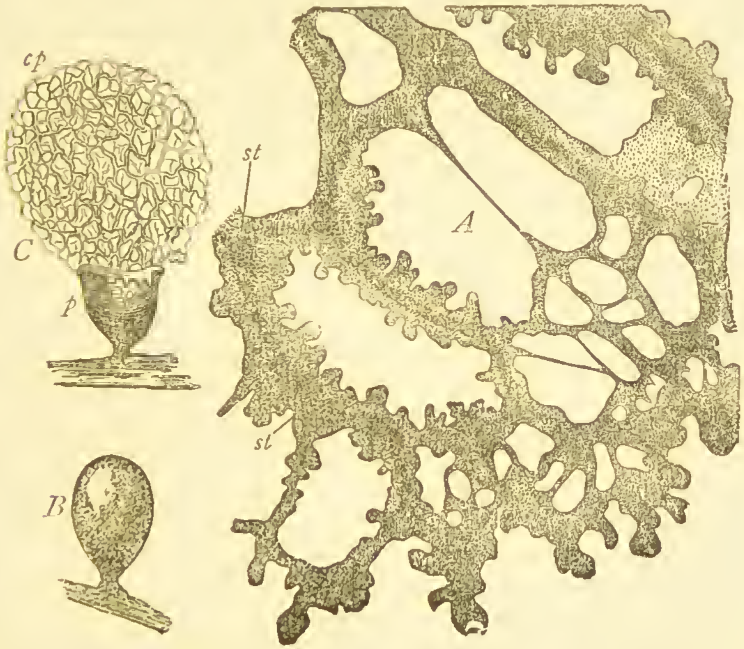


Fig. 828. *A.* Plasmodium of a Myxomycete (×300). *B.* A fructification still closed. *C.* After rupture of the wall, *p*, and extrusion of the capillitium, *cp.* ×20. (After De Bary.)

the Myxomycete is at some time characterised by this behaviour, which recalls the condition of the form of animal known as the Amœba. While the separate masses are still motile they can multiply by cell-division, which has been ascertained to be preceded by karyokinesis. Ultimately the amœboid masses collect into a *plasmodium*, without fusion of the nuclei, so forming a kind of cœnocyte (*fig.* 828, *A*). Like the constituent cells, the plasmodium can creep about by means of pseudopodia. A familiar example of this fungus is the so-called 'flowers of tan' (*Æthalium*), which is found in the form of jelly-like lumps in tan yards.

The plasmodium in time comes to rest, and gives rise to one or more gonidangia. In the latter case it divides into as many pieces as the gonidangia ultimately formed. The whole of the mass or of each piece shrinks up into a rounded body which shows differentiation into a hardened outer portion or wall, and an inner mass which gives rise to gonidia. The substance of the inner portion produces a peculiar network of protoplasmic filaments, the *capillitium* (*fig.* 828, *C*, *cp*), among which are formed the gonidia, these being furnished with a cell-wall which each secretes independently. Sometimes the gonidangium is stalked, sometimes sessile; occasionally a protrusion of the stalk into the gonidangium forms a kind of *columella*. The gonidia after a time are liberated, or scattered by the elastic capillitium, and give rise to the amœboid masses already described.

Sub-Class III. Phycomycetes.

In this group we have undoubted cases of sexual reproduction, which take the form of conjugation or fertilisation, thus giving rise to two sections, the *Zygomycetes* and the *Oömycetes*. In both groups the mycelium is unseptate, or incompletely septate, being cœnocytic in its construction.

Zygomycetes.—The form most generally known in this group is the common mould, *Mucor Mucedo*, found generally on dung and other decaying organic matter. The gonidium gives rise to a copiously branched mycelium, which ramifies very freely in the substratum. When well established it throws up aerial branches which terminate in globular heads or gonidangia. A septum is formed close to the apex of the hypha, cutting off a small head which grows and becomes globular. The lower cell grows also, and projects into the swollen portion, forming a columella (*fig.* 822, *m*). The contents of the terminal cell break up into a number of gonidia. The wall of the gonidangium usually becomes impregnated with crystals of calcium oxalate.

The sexual reproduction is carried out by means of undifferentiated gametes. Two hyphæ from the vegetative part of the mycelium approach each other, and a septum cuts off from each a small cell, which is the gametangium. The two gametangia come into contact, and the walls between them are absorbed, so that the gametes, which are the undifferentiated protoplasm of the gametangia, fuse together, forming a *zygospore* (*fig.* 829). This grows into a globular body which secretes round itself a thick cuticularised wall. After a period of rest, this body germinates, putting out a small mycelium, called a *promycelium*, which gives rise to a sporangium (*fig.* 829, *sp*) much like the gonidangia borne upon the ordinary body of the fungus. This promycelium represents the sporophyte, the ordinary form being the gametophyte.

In some species of *Mucor* the gametangia are solitary and conjugation does not take place; the body produced parthenogenetically by such a gametangium is called an *azygospore*.

Fig. 829.

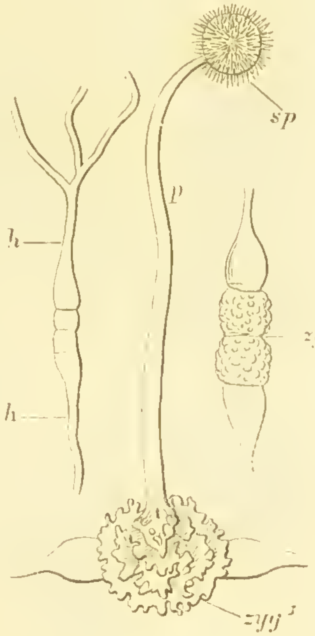


Fig. 829. Conjugation in *Mucor Mucedo*. *h*, *h*. Two hyphæ which have come into contact at their apices, and each has cut off from itself a cell. *zyg*. Zygospore resulting from the fusion of these cells. *zyg*¹. Adult zygospore after germination. *p*. Promycelium bearing a sporangium, *sp*.

Under unfavourable conditions of nutrition, as when the hyphæ are all immersed in liquid, the mycelium of *Mucor* may divide up into a number of oidium-like cells resembling yeast cells. This is called the *Torula* form; it is capable, like yeast, of setting up alcoholic fermentation in a sugary fluid. Sometimes the separate cells are large and thick-walled, when they are known as *Chlamydospores*.

There are two other groups in this sub-class, the *Chytridiaceæ* and the *Entomophthoraceæ*. The former produce zoogonidia in ordinary gonidangia and in others which are specially thick-walled, the latter being formed after a period of rest. Zygospores also occur, but the differentiation of the sexual organs is not so complete as in the Mucorinæ. The Entomophthoraceæ are parasitic on insects. They differ from *Mucor* chiefly in the mycelium being incompletely septate, being thus composed of a number of cœnocytes, instead of a single one.

Oömycetes.—The chief members of this group are the *Peronosporeæ* and the *Saprolegniæ*. The former are chiefly parasitic, causing many of the diseases of Phanerogamic plants, though saprophytic forms occur. A typical example of them is the fungus *Phytophthora infestans*, which causes the potato disease. The hyphæ ramify usually between the cells of the plants, sending haustoria into their interior, and so absorbing their nutritive juices (*fig.* 830). The mycelium sends out hyphæ through the stomata of the leaves, and these bear gonidangia at their apices. In *Phytophthora* these hyphæ are branched and bear several gonidangia; in *Peronospora* each bears a single one. In some cases the gonidangium gives rise to zoogonidia; in others it behaves like a gonidium and puts out a hyphæ directly.

FIG. 830.

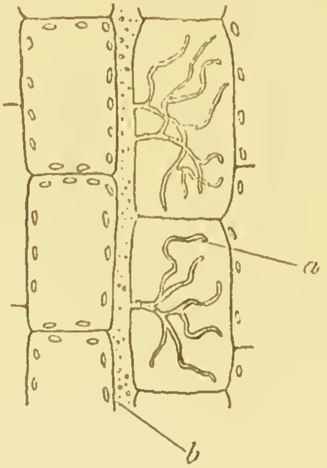


Fig. 830. Four cells of potato plant, infested with *Phytophthora*. *b*. Hypha running between the cells and sending haustoria, *a*, into their interior.

The sexual reproduction of this group is seen best in such forms as *Pythium* and *Cystopus*. In the former a hypha cuts off a cell at its apex, which becomes swollen and rounded, forming an oogonium. Its contents give rise to a single oosphere, part only of the protoplasm being concerned in its formation, while the rest forms a peripheral layer, the *periplasm*. Though the oogonium contains a large number of nuclei, only one of these apparently is retained in the oosphere, the rest remaining in the periplasm. The male organ, often called a *pollinodium*, is produced in a similar manner from a hypha, which in some cases springs off as a lateral branch from that which bears the oogonium, and in others from an adjacent one. The contents of the pollinodium show a differentiation similar to that of those of the oogonium, a generative cell or gamete being separated from a layer of periplasm. In its growth the pollinodium becomes closely applied to the oogonium, and penetrates its wall by means of a delicate tube which serves to conduct the male cell into the oogonium, where it fuses with the oosphere, forming the *oospore* or *zygote*, which clothes itself with a cell-wall. After a period of rest the zygote germinates, giving rise to a small promycelium, which in time produces spores.

Fig. 831.

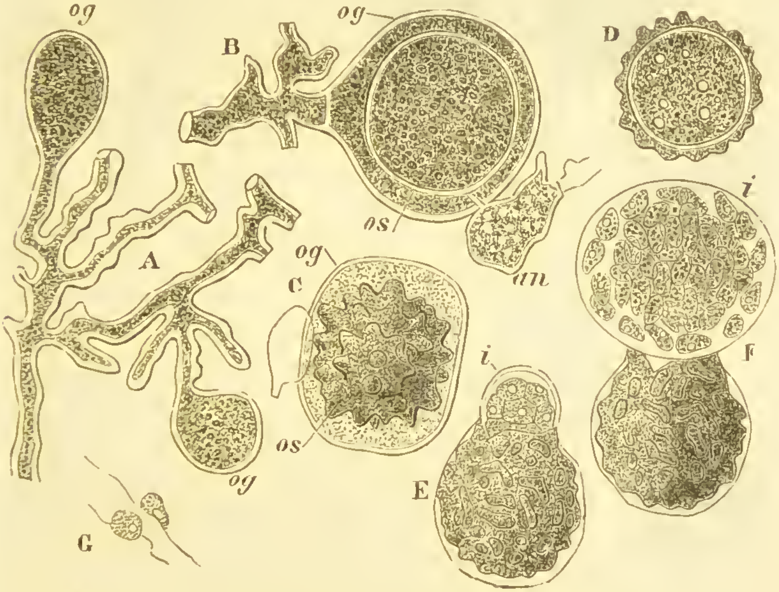


Fig. 831. A. Branched mycelium of *Cystopus*, with young oogonia, *og*, *og*. B. Portion of mycelium bearing oogonium, *og*. with the oosphere, *os*; and antheridium or pollinodium, *an*. C. Mature oogonium, with *os*, the oospore or zygote. D. Mature oospore. E, F. Formation of swarm-spores or zoospores, G, from the oospores. *i*, *i*, Protruded endospore. After De Bary.

Several other genera behave like *Pythium* in these processes; in *Cystopus*, however, the result of germination is the production of a number of zoospores (*fig.* 831).

The Saprolegniæ all live in water, being parasitic in some cases, though often saprophytic. The Salmon disease is due to one species of this group. The gonidangia are here club-shaped and give rise to zoogonidia (*fig.* 833). The sexual organs are produced in a manner similar to that which is met with in the last group. but the oogonium usually contains several oospheres (*fig.* 833). In their formation there is no periplasm left. The pollinodia usually send tubes into the oogonia, but there is no passage of the male gamete. The oospheres become oospores without fusion with the latter, that is parthenogenetically.

In the Oömycetes, as in the Zygomycetes, antithetic alternation of generations occurs, but the sporophyte is always small and inconspicuous. It is represented by the zygote itself in such forms as *Cystopus*, where it at once gives rise to zoospores; in *Pythium*, &c., the promycelium is the sporophyte. Some forms have apparently no such alternation, as the oospores or zygotes give rise to sexual plants.

FIG. 832.

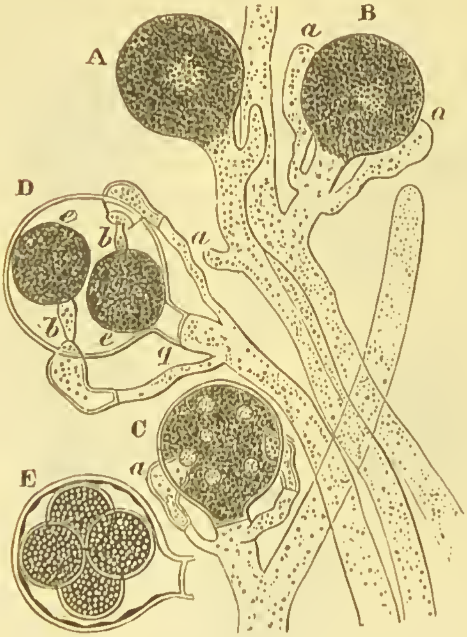


FIG. 833.

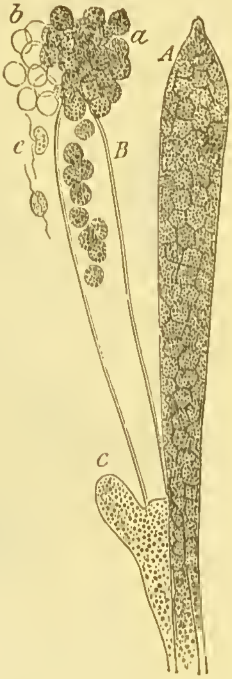


Fig. 832. Oogonia and antheridia of *Achlya lignicola.* The letters A to E indicate the course of development. The protoplasm of a cell or branch of a cell collects into a globular form A, B, and by the formation of a septum, D *q*, becomes an independent cell (the oogonium). The protoplasm then breaks up into two or more parts, D, *e*, *e* (oospheres), which quickly become spherical, as seen in D, secrete a cell-wall E, and become oospores. After Sachs. —*Fig.* 833. Two gonidangia of *Achlya.* A. Closed. B. Ruptured and allowing the zoogonidia, *a*, to escape. *b*. Mother cells of the latter after escape of *c*, the zoogonidia, from them.

Sub-Class IV.—Ascomycetes.

In this group the mycelium is made up of a number of cœnocytes, each of the apparent cells with which the hyphæ are divided containing several nuclei. The mycelium is thus incompletely septate. The fungi are in some cases saprophytic, in others parasitic. Sexual reproduction appears to occur in some forms, but it is always rudimentary, and in many cases its existence is disputed. In several members of the group complex organs occur which suggest sexuality, but it may be that, as in the Saprolegniæ, actual fertilisation does not take place. It is, however, convenient to describe these structures as sexual, while reserving the question of the actual fusion of the gametes.

The group derives its name from the fact that whether produced after sexual fusion, or parthenogenetically, the spores arise in closed cells known as *asci*. There is much variety in the mode of origination of the latter, but they agree in that there is no case of a differentiated female gamete giving rise to them. The fungi of this group in this respect resemble the Rhodophyceæ of the group of Algæ.

The sexual organs show a great deal of difference in the degrees of their complexity. The female organ is usually an *archicarp*, consisting of a coiled portion, known as a *carpogonium*, with sometimes an elongated part, called a *trichogyne* (*fig.* 834). In many forms the trichogyne is wanting, and only the coiled portion is found. The male organ is sometimes a pollinodium, much like that of the preceding group, and produced in the immediate neighbourhood of the carpogonium. Sometimes it is a filament producing small cells by abstriction. These filaments are known as *sterigmata*, and are borne in special depressed receptacles called *spermogonia* (*figs.* 835 and 836). The separate cells correspond to antherozoids, but are incapable of motion and are clothed with a cell-wall. They are known as *spermatia*. The result of the union of the contents of the pollinodium or spermatium with those of the carpogonium is a fructification called the *ascogonium*, which is the sporophyte of the fungus.

The nature of these spermatia is, however, still disputed. Though in some cases they appear to act as male cells, in others they have been observed to germinate independently, that is to act as spores or gonidia.

In the simplest case of sexual union, which is that of *Eremascus*, two hyphæ coil round each other. These correspond to the carpogonium and the pollinodium respectively. Their contents are said to fuse, and as the result a large globular body is produced at the apex of the coil, the contents of which divide into eight spores.

In *Eurotium Aspergillus* (*fig.* 837) a little more difference is found between the two hyphæ. The female forms a coil, and from the base of it the pollinodium arises. It becomes closely adpressed to the carpogonium, and fusion of the contents of the two is said to occur. From the base of the carpogonial filament other filaments arise which grow round and envelop it. The coiled carpogonium becomes septated, and from each segment a little protrusion arises, which enlarges and becomes an ascus, and forms in its interior eight spores. The investment becomes also septated, and forms a thick wall to the whole body. From its cells ingrowths arise which gradually fill up the spaces between

Fig. 834.

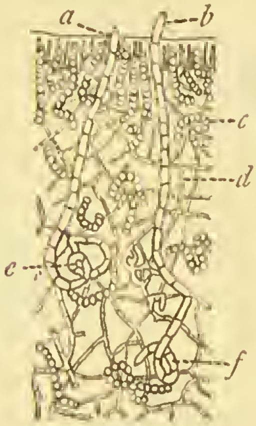


Fig. 836.

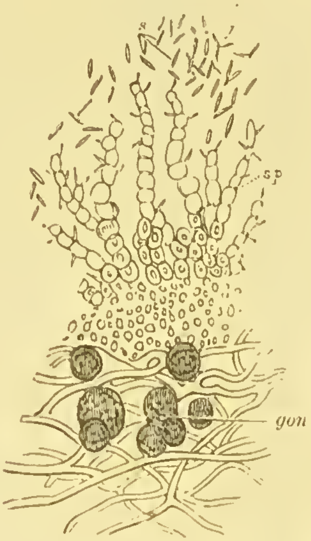


Fig. 835.

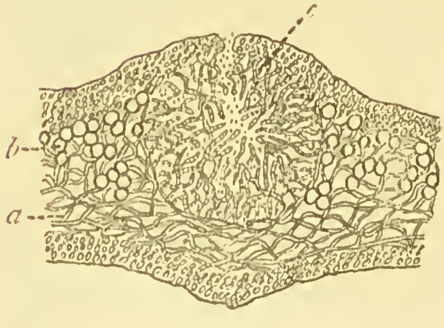


Fig. 834. Section of upper portion of thallus of a lichen, showing archicarps. *a*, *b*. Trichogynes. *e*, *f*. Coiled basal portion of archicarps. *c*. Nostoc filaments. *d*. Fungal hyphæ. After Kny. —— *Fig.* 835. Section of spermogonium of a lichen. *a*. Hyphæ of the thallus. *b*. Algal cells. *c*. Sterigmata. —— *Fig.* 836. Highly magnified fragment from the wall of a spermogonium of *Parmelia parietina*. *sp*. Articulated sterigmata or spermatophores. *s*. Spermatia. *gon*. Algal cells.

the coils of the carpogonium, forming a solid mass of pseudo-parenchyma. The body so formed is then known as the ascogonium or *ascocarp*. From the fact that it remains closed and produces its spores internally, it is sometimes called a *cleistothecium*.

Fig. 837.

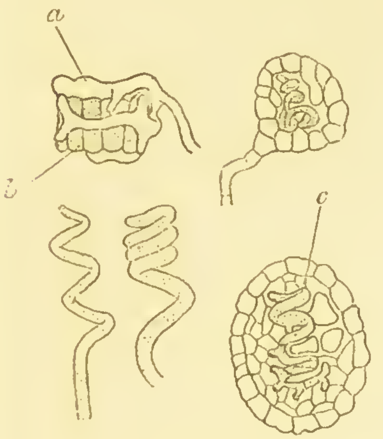


Fig. 839.

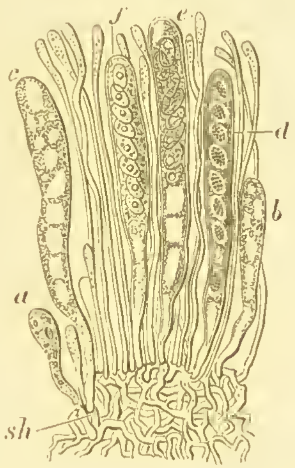


Fig. 838.

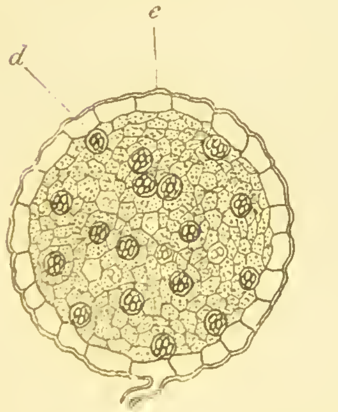


Fig. 840.

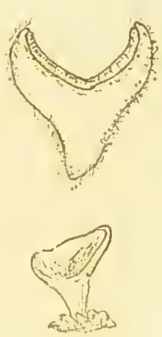


Fig. 837. Development of the cleistothecium of *Eurotium*. *a*. Pollinodium. *b*. Carpogonium. *c*. The carpogonium beginning to form asci. After Kny.——*Fig.* 838. Mature cleistothecium of *Eurotium*. *e*. Wall. *d*. Asci containing ascospores. After Kny.—— *Fig.* 839. Hymenial layer of the mycelium or hyphæ of *Peziza convexula*. *a*, *b*, *c*, *d*, *e*, *f*. Successive stages of development of the asci and ascospores intermixed with slender paraphyses. After Sachs.—— *Fig.* 840. Perithecium of *Peziza* (natural size), with section showing hymenial layer (slightly magnified). After Kny.

The fungus *Collema*, which is generally found in symbiotic relation with an Alga, may be taken as an illustration of another type. The female organ is a septated coiled filament embedded a little below the surface of the organism (*fig.* 834). Its upper end is prolonged into a tapering filament, the trichogyne, which projects above the surface. A spermatium liberated from the spermogonium is floated passively to the trichogyne and becomes attached to it. The walls deliquesce at the point of contact, and fusion of the contents takes place. The trichogyne then withers and the carpogonium develops and pushes its way to the surface, where it expands into a flattened disc which is known as an *apothecium.* Hyphæ from the sterile tissue are interwoven with the filaments from the carpogonium, so that the apothecium is derived from both. The surface layer of the apothecium is known as the hymenial layer (*figs.* 839 and 840). It consists of a number of asci derived from the carpogonium, and of sterile filaments springing from the vegetative hyphæ. These are called *paraphyses.* Each ascus develops eight spores from part of its protoplasm, the rest remaining as *epiplasm.*

In some cases the apothecium persists for a long time and produces new asci towards its margins.

In some species the fructification is in the form of a deep or shallow cup, sometimes nearly closed. This is called a *perithecium* (*fig.* 840).

The group of the Saccharomycetes is now generally referred to this subclass. These plants are represented by the *Yeasts,* which have the power of setting up alcoholic fermentation in sugary fluids. They are simple cells of rounded or ovoid form which multiply with great rapidity by a process of budding. When growing rapidly, sometimes chains of cells are formed, owing to the budding taking place before separation of the cells. Under certain conditions, usually when badly nourished, the yeast cell forms four spores by free cell-formation in its interior. Each such cell may be looked upon as an ascus and the four spores as ascospores.

FIG. 841.

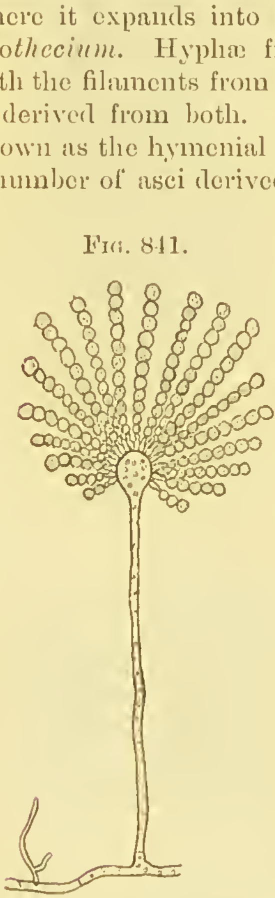


Fig. 841. Stylogonidia of *Eurotium,* produced by abstriction from sterigmata.

Quite recently a form of sexual reproduction has been observed in one species of Yeast. Two cells lying close to one another put out short necks or beaklike processes, and fusion of these projections occurs. Their contents mingle, and what is apparently true conjugation takes place, the nuclei fusing together. After a period of rest the zygospore so formed gives rise to true spores in its interior, which are apparently indistinguishable from those ordinarily occurring in an ascus.

Besides these so-called sexual processes, most of these fungi can produce gonidia in great numbers. They are borne upon erect aerial hyphæ by a process of abstriction from their terminal cells called sterigmata (*fig.* 841). Each sterigma can thus produce a chain of gonidia. Sometimes the aerial hypha or gonidiophore terminates in a single sterigma, sometimes it branches near the apex, forming several. Sometimes the gonidiophores are found in numbers in special receptacles called *pycnidia*.

We have thus an alternation of generations in most members of the group, the ordinary mycelium being the gametophyte, and the ascocarp the sporophyte. Homologous alternation almost always occurs, many gametophytes in succession bearing only gonidia, till one appears which produces the sexual organs. In a few genera, however, no gonidia are found.

A curious case of homologous alternation occurs in some forms where two kinds of gametophyte are met with. The fungus producing Ergot (*Claviceps*) is an example of this. The first form consists of a feltwork of mycelium, filling the ovary of the Rye or Wheat plant, and giving rise, by abstriction, to numbers of gonidia (*fig.* 843). This form is known as the *Sphacelia*. Later in the year the mycelium becomes very dense and hard, and protrudes from the ear as a black elongated body which is known as a *sclerotium* (*fig.* 842). After a period of rest extending through the winter, the sclerotium germinates, putting out a number of short protrusions, each composed of a number of hyphæ. Each of these, which are called *stromata*, bears a rounded head, which is covered by a number of depressions. In each depression is developed a perithecium (*figs.* 844, 845, and 846), the asci of which develop each eight filiform ascospores (*fig.* 847). These, when they germinate on the flowers of the host-plant, again produce the sphacelia form.

Sub-Class V.—Æcidiomycetes.

In this group are included two orders of parasitic plants, which are characterised by a still further degradation of the sexual processes. Indeed it is doubtful if any sexual organs exist, though a peculiar form of fructification, the *æcidium*, which occurs in some of the members of the group, has been considered to be homologous with the ascogonium of the preceding

Fig. 842.

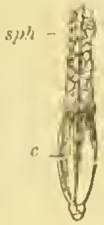


Fig. 843.

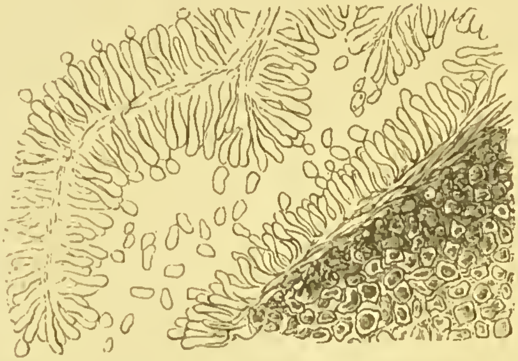


Fig. 842. Young sclerotium, *c*, of *Claviceps* growing up and supplanting the old sphacelia, *sph.*—— *Fig.* 843. Section through the junction of the sphacelia with the sclerotium of *Claviceps*, showing formation of gonidia.

Fig. 844.

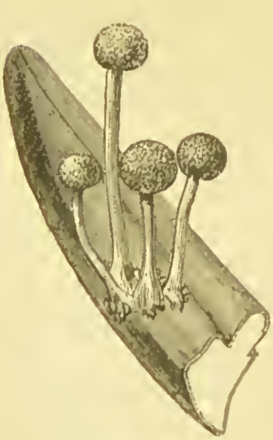


Fig. 845.

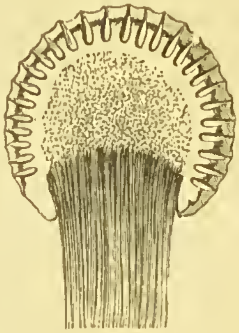


Fig. 844. Portion of the horn-shaped sclerotium of *Claviceps purpurea*, or the Ergot Fungus, bearing four stromata.——*Fig.* 845. Longitudinal section of a stroma, magnified, showing the perithecia. After Tulasne.

sub-class. The gametophyte is consequently potential and not actual, in most if not in all cases. It is very polymorphic, and bears several different kinds of gonidia, all produced by abstriction.

The most characteristic fungus of this group is *Puccinia* *graminis*, which forms the *rust* of wheat. It has a very peculiar life history, inhabiting two host-plants in different stages of its existence. In the first of these it is found infesting the stems and leaves of Wheat and other grasses, patches of whose tissues are penetrated by an incompletely septate mycelium which sends haustoria into the cells. During the summer this mycelium produces patches of gonidia, each borne upon a short stalk. These develop underneath the epidermis of the host, and, being of a yellow or reddish colour, give the part a rusty appearance. These are known as *uredospores* or *uredogonidia*. These escape by rupture of the epidermis (*fig.* 848, *A*), and are blown upon other grass plants, where they germinate, and the hypha penetrates the host through a stoma. In the interior a mycelium is produced, which again produces patches of uredogonidia.

Fig. 846.

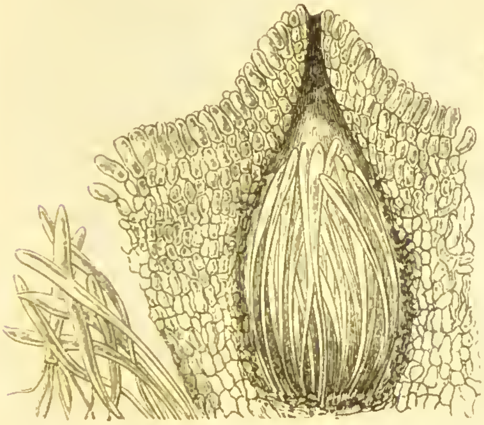


Fig. 847.

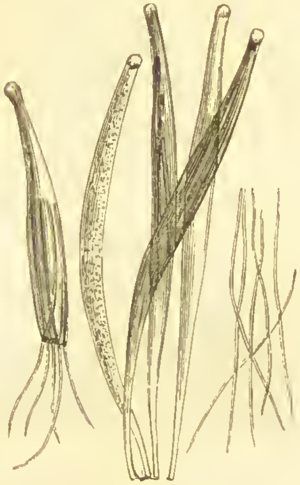


Fig. 846. A single perithecium of *Claviceps purpurea*, magnified, showing the contained asci. After Tulasne.——*Fig.* 847. Asci of the same, containing the long slender ascospores. After Tulasne.

Towards the end of the summer the same mycelium gives origin to black patches which are visible upon the straw. These are composed of numbers of gonidia, two together upon a single stalk, developed as before by abstriction (*fig.* 849). These, which are called *teleutospores*, or *teleutogonidia*, have thick black walls and are very resistent. They remain quiescent till the spring, when one or both of them germinates, producing a small promycelium, usually of four cells. Each cell puts out a small gonidiophore, from which a small gonidium, called a *sporidium*, is developed by abstriction (*fig.* 848, *B*). From a resemblance to the cells which abstrict the gonidia in the next group, these cells are sometimes called *protobasidia.* The sporidium is a very small thin-walled structure, and from its lightness it is easily transported by the wind. It is incapable of developing a mycelium upon the grass, but if it falls upon the leaf of the Barberry, it germinates, sending a hypha through the epidermis, instead of penetrating a stoma like the uredogonidium. The mycelium developed from this hypha forms a dense network in the intercellular spaces of the leaf. At particular spots upon the leaf, brown pustules make their appearance, in which two kinds of receptacles appear. Some on the upper surface of the leaf are much like the spermogonia of the Ascomycetes, and bear the same name. They produce spermatia in the same way as the latter. Upon the under surface large spherical bodies are formed (*fig.* 851), containing a hymenial layer of sterigmata which cut off from their apices a succession of gonidia known as *æcidiogonidia.* There are large numbers of chains of these thus produced in the globular mass, which is known as an *æcidium.* The whole æcidium has a wall derived from the sterile hyphæ. When mature it ruptures and the gonidia escape. These are carried in their turn to other grass plants, and there germinating,

FIG. 848.

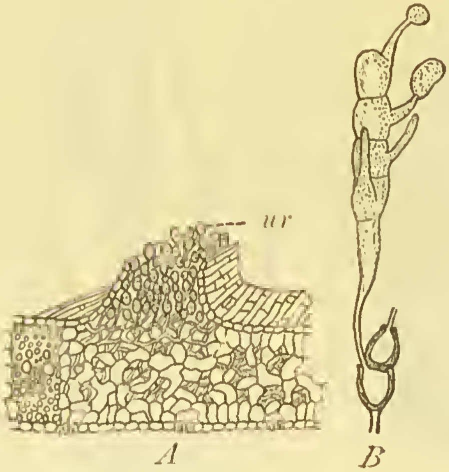


FIG. 849.

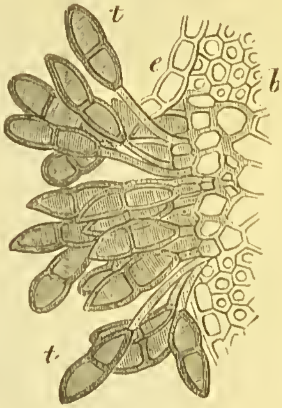


Fig. 848. *A.* Grass leaf infested with *Puccinia graminis*, showing the uredospores, *ur*, bursting through the epidermis of the leaf. *B.* Teleutospore germinating and producing promycelium with sporidia.——*Fig.* 849. Teleutospores of *Puccinia graminis* bursting through epidermis of straw. After Kny.

reproduce the uredo form, entering the grass through the stomata.

This plant and those like it, which thus inhabit two host-plants in their life cycle, are called *heterœcious*.

There are many of these rusts, which vary in several ways. The teleutogonidia sometimes occur in strings of more than two. Sometimes the æcidium form inhabits the same host as the uredo form, when the fungus is said to be *autœcious*. Sometimes again one or the other phase of the life cycle does not occur.

Fig. 850.

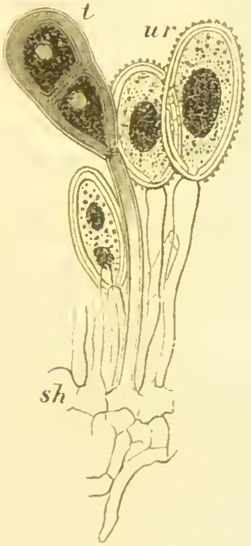


Fig. 851.

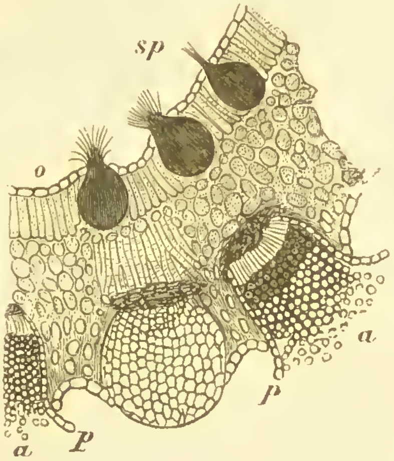


Fig. 850. Group of three uredospores, *ur*, and one teleutospore, *t*, springing from mycelium, *sh*. —— *Fig.* 851. Section through leaf of the Barberry infested with *Puccinia graminis*. *o*. Epidermis of upper surface of leaf. *sp*. Spermogonia. *p*, *p*. Layers of cells (*peridium*), surrounding *a*, *a*, the æcidium fruits. After Sachs.

Though the æcidium is held by some to correspond to the ascocarp or ascogonium of the Ascomycetes, no sexual process causing its development has been discovered.

The rusts constitute the family of the Uredineæ, named from the uredo form of the fungus.

The other family included in this sub-class is that of the Ustilagineæ, or smuts. They differ from the Uredineæ in not producing æcidia. Like them the mycelium infests the tissue of grasses, ultimately making its way into the ovary of the latter, replacing its normal contents by a mass of black resting gonidia. These when liberated germinate, forming a small promycelium on which sporidia of curious shape are borne. These sporidia sometimes coalesce in pairs, sometimes remain separate. On germination they either produce the original form of mycelium, or give rise to another promycelium bearing sporidia. The latter then produce the first form.

Sub-Class VI.—Basidiomycetes.

This group includes the Mushrooms, Puff-balls, &c. It is characterised by the entire absence of sexual reproductive organs. The mycelium, which is incompletely septate, burrows throughout the substratum on which the fungus grows, and sends up above the surface large fructifications which bear the spores or gonidia. These are formed by abstriction from special cells known as *basidia*, which give the name to the group. The form of the fungus is always that of a potential gametophyte, but the power of producing gametes is absent.

Fig. 852.

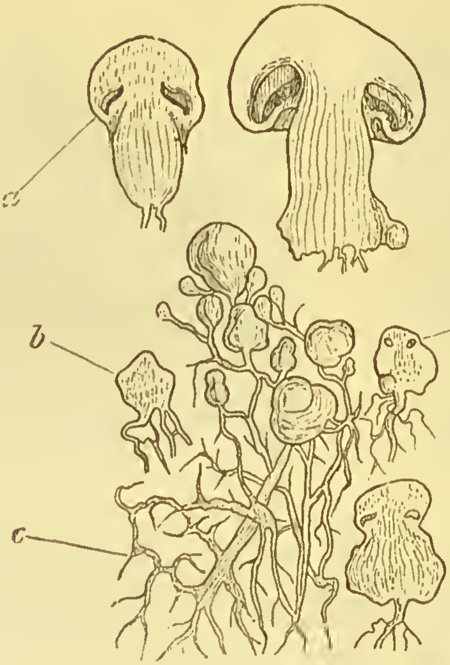


Fig. 852. Development of the Mushroom. *c*. Mycelium. *b*. Early stage of the development of the gonidiophore. *d*. Later stage, showing origination of the gill-chamber. *a*. Later stage, showing commencement of formation of the gills. After Sachs.

The distinguishing feature of the group is the large sub-aerial fructification or gonidiophore. Several varieties of this are found, of which the most familiar is that produced by the common mushroom (*Agaricus campestris*) (*fig.* 852). A conical or pear-shaped outgrowth appears upon the mycelium, consisting of a number of hyphæ closely cohering together and growing at their apices. The direction of the growth soon changes, the hyphæ spreading outwards to form a prominent head which extends centrifugally. An annular cavity is formed in this near its lower part, which increases in size as the head extends. The head can now be recognised as distinct from the lower portion of the hyphal mass, and is known as the *pileus*, the lower part or stalk being called the *stipes*. In the air cavity a number of plates or lamellæ are developed, which radiate from the centre to the circumference. These form the gills of the mushroom, and on them the spores or gonidia are developed. As the growth of the stipes proceeds, the part of the pileus below the air cavity becomes very much stretched and forms a membrane, extending from the stipes to the lower margin of the pileus. It ultimately ruptures and leaves the gills exposed. This membrane is known as the *velum partiale*. The gills are composed of hyphæ, which run parallel along their length, ultimately curving slightly outwards. These constitute the *trama* (*fig.* 853, *f*), and

Fig. 853.

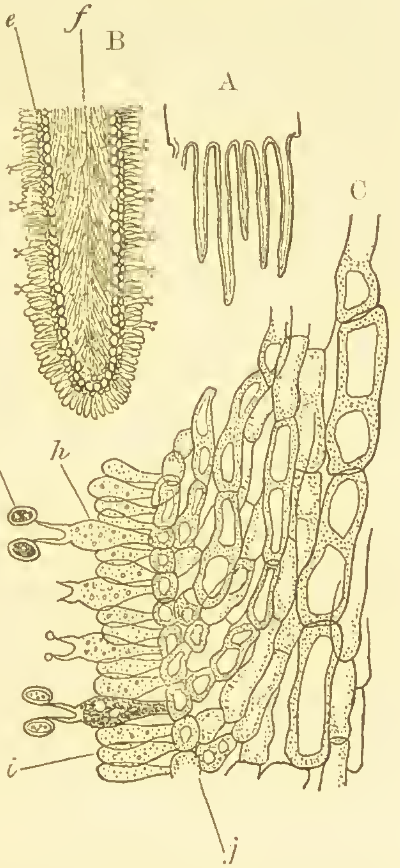


Fig. 853. A. Section of five gills of the Mushroom. B. One gill more highly magnified. *f.* Trama. *e.* Hymenial layer. C. Hymenial and sub-hymenial layers. *h.* Basidia. *g.* Basidiospores. *i.* Paraphyses. *j.* Sub-hymenial layer. After Sachs.

are covered by the *hymenial layer*, which is composed of short cells derived from the hyphæ of the trama, set at right angles to its long axis. These cells are of two kinds, sterile ones, or *paraphyses*, and those which give rise to the gonidia, the *basidia*. Each basidium puts out two or four delicate outgrowths, closely resembling those of the promycelium of the Uredineæ, and from each of these a single gonidium or spore is abstricted. These, from their mode of origin, are known as *basidiospores* or *basidiogonidia* (*fig.* 853, c, *g*). A layer of small cells closely packed together lies between the hymenial layer and the trama. It is called the *sub-hymenial layer* (*fig.* 853, *j*).

The form of the fructification varies a good deal in different groups. In some the hymenium is exposed from its first formation; in others it is covered for a time by the *velum partiale*; in yet others it is always surrounded by a membrane, which is then known as the *peridium*, as in the Gasteromycetes, or the *velum universale*, as in some Agaricinæ. The hymenium is also variously arranged; in the true mushrooms it covers the gills as described; in the family Polyporeæ it lines pits or tubes on the under surface of a flattened expansion; in the Gasteromycetes it is formed in the interior of the fructification in a number of chambers.

The basidia are usually unicellular, but in one group, the Protobasidiomycetes, they are divided by septa, sometimes transverse, sometimes longitudinal, forming four cells, each of which produces a single gonidium. These forms approach the promycelium of the Uredineæ very closely.

Vegetative reproduction occurs in this group, by the formation of gemmæ, which commonly arise on the vegetative mycelium as oidium cells (page 82). Some of the Basidiomycetes also produce sclerotia, masses of closely matted hyphæ which may become detached from the mycelium and germinate after a period of quiescence.

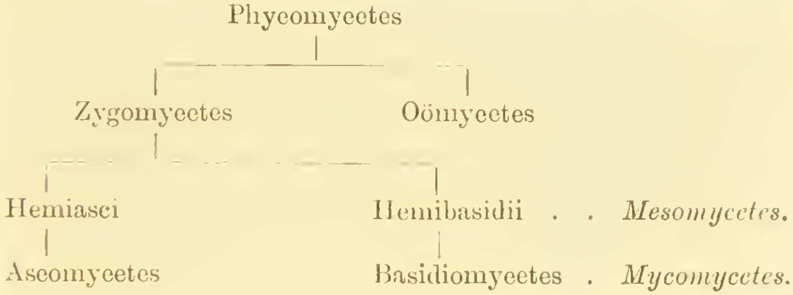
In recent years the investigations of Brefeld and his pupils have led to a different classification of the Fungi, for which there is much to be said.

The Myxomycetes are taken out of the group and made a separate class, of equal position to the Algæ and Fungi, great stress being laid on their resemblance to the animal Mycetozoa or Rhizopods.

The Fungi proper are subdivided into three classes, and these into sub-classes as under :—

- Class I. Phycomycetes.
  - Sub-Class 1. Zygomycetes.
  - Sub-Class 2. Oömycetes.
- Class II. Mesomycetes.
  - Sub-Class 1. Hemiasci.
  - Sub-Class 2. Hemibasidii.
- Class III. Mycomycetes.
  - Sub-Class 1. Ascomycetes.
    - Series 1. Exoasci.
    - 2. Carpoasci.
  - *Additional.* Ascolichenes.
  - Sub-Class 2. Basidiomycetes.
    - Series 1. Protobasidiomycetes.
    - 2. Autobasidiomycetes.
  - *Additional.* Basidiolichenes.
- Additional. Fungi imperfecti.

According to this school these groups can be arranged in the form of a tree, indicating the probable line of descent or succession of forms. The Phycomycetes are held to be the primitive type and to be descended from sporangia-bearing Chlorophyceæ.


Phycomycetes
Zygomycetes
Oömycetes
Hemiasci
Hemibasidii . . *Mesomycetes.*
Ascomycetes
Basidiomycetes . *Mycomycetes.*

The Phycomycetes form the lowest group and include all the forms which, in addition to asexual reproduction, show the sexual method by fusion of differentiated gametes. They thus include the Mucorini, the Peronosporeæ, and the Saprolegniaceæ.

The Mesomycetes comprise the intermediate forms between the Phycomycetes and the Ascomycetes and the Basidiomycetes respectively. They approach the latter in their vegetative organs, especially their incompletely septate mycelium. They differ from them in not possessing definite asci or basidia. They have no sexual organs, differing thus from the Phycomycetes.

The Hemiasci are a small and comparatively unimportant group; the Hemibasidii include the Ustilagineæ, or smuts.

Through the Mesomycetes the line of descent passes to the Ascomycetes on the one side and the Basidiomycetes on the other, which together form the group of the Mycomycetes. These have septate hyphæ, and produce their asexual reproductive cells at some time or other in asci or on basidia. Sexual reproduction is unknown, except the doubtful cases mentioned as occurring in the Ascomycetes.

The Ascomycetes embrace, generally speaking, the forms included under the same name in the older classification, except that the Saccharomycetes are excluded. The Ascolichenes are held to belong to this group and are not put into a separate class. The Ascomycetes are divided into two series, the Exoasci, where the asci are simple and free, and the Carpoasci, where they are gathered into the various forms of fructification already described.

The Basidiomycetes are a larger group than in the old system, as the Uredineæ are included in it. The latter are referred to the series Protobasidiomycetes on account of the mode of germination of the teleutospore, which gives rise to what has been already described and has so far been called a promycelium on which are borne sporidia. This promycelium is held to be a *protobasidium*, from each cell of which a basidiospore is segmented. The Autobasidiomycetes comprise what under the older system were called Basidiomycetes, except the Auriculariaceæ and the Tremellaceæ, which, with the Uredineæ, form the first series.

The Basidiolichenes are held to be members of this group, though they are not referable to either of the two series.

Finally, the Saccharomycetes are separated from the rest on the ground that their life history is very imperfectly known, and that they possibly are only stages in the life cycle of some polymorphic form of the higher Fungi. They are classified as an additional group under the name *Fungi imperfecti.*

Class III.—LICHENES.

The propriety of considering the Lichens as a separate class is perhaps open to discussion. Before their true nature was understood they ranked as such, but when they were ascertained to be largely fungal in their composition, and to contain algæ in their tissues, they were perhaps hastily relegated to the Fungi, assuming them to be parasitic on the algæ within them. Further study has shown them to be symbiotic organisms, the alga and the fungus living together to the mutual advantage of both. The constituents may also sometimes vary, the same algæ growing with different fungi and *vice versa*. They may consequently be restored to something of their old position.

Fig. 854.

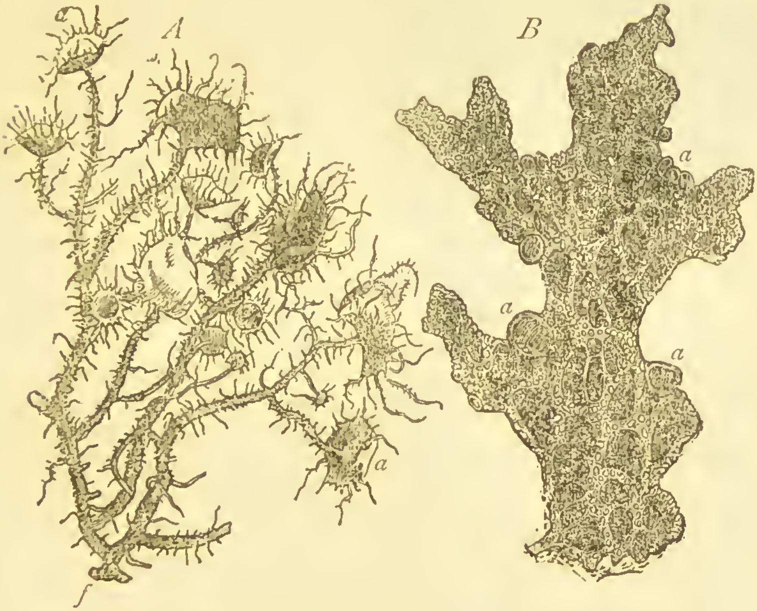


Fig. 854. A. *Usnea barbata*, a fruticose lichen (natural size). *B. Sticta pulmonacea*, a foliaceous lichen. *a*. Apothecia. After Sachs.

The lichens are thallophytes of various form, living on old trees, rocks, &c., and presenting always a peculiar withered appearance. According to their habit, they may be divided into *fruticose*, *foliaceous*, and *crustaceous* lichens.

The fruticose forms have an erect thallus, which branches in a somewhat shrubby fashion. A typical lichen of this type is *Usnea barbata* (*fig.* 854, *A*). The *foliaceous* ones are flattened and grow closely and pressed to the substratum. The thallus is wavy and its margin lobed. The *crustaceous* forms are usually very indistinct, their outline indefinite, and only their fructification distinctly seen. They become so attached to their substratum that they cannot be detached from it completely without injury (*fig.* 855).

Fig. 855.

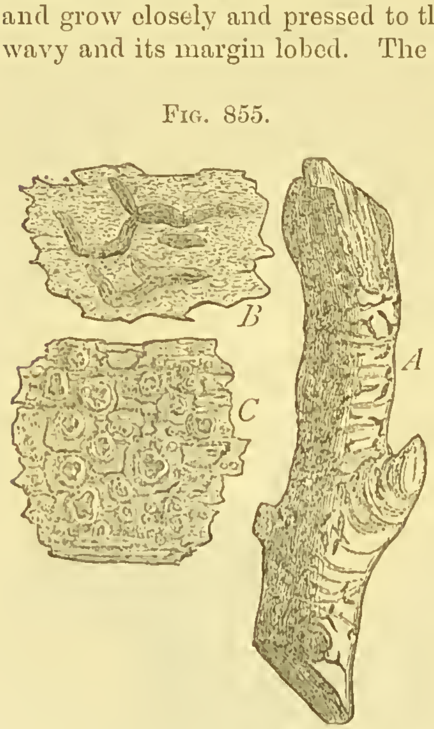


Fig. 855. *A*, *B*. *Graphis elegans*, a crustaceous lichen growing on the bark of the Holly. *A*. Natural size. *B*. Slightly magnified. *C*. *Pertusaria Wulfeni*, another crustaceous lichen (slightly magnified). After Sachs.

In composition the thallus consists of a fungoid mycelium, which is very closely matted together. It includes in its substance certain algæ, which may be distributed throughout it or confined to a definite layer near the upper surface, constituting the *homoiomerous* and *heteromerous* kinds respectively. In the former case the algæ generally belong to the Cyanophyceæ, and in the latter to the Chlorophyceæ. This distinction is, however, by no means absolute. The fungal constituents are chiefly referable to the sub-class Ascomycetes, and so great is their prominence that the whole group has by some botanists been described as a family of this sub-class. Other fungi, however, are now known to enter into the symbiotic relationship with algæ, especially several belonging to the Basidiomycetes.

The proof of the true character of the lichens is based upon the facts that the two organisms can be cultivated separately, and that if the spores of one of the fungi be sown among some of the algæ the composite organism can be produced.

A section of the body of one of the heteromerous foliaceous lichens is shown in *fig.* 856, where the distribution and character of the fungal mycelium are shown. *g* is the layer of algæ which are symbiotic with the fungus. In the fruticose forms the centre of the branches is occupied by a dense strand of hyphæ running longitudinally. This is surrounded by a looser layer which is in turn enclosed by a compact cortex. The algæ are found in the loose tissue.

The reproductive organs of the lichen are always produced by the fungal constituent. The fructification is usually an apothecium, and is said in some cases to be produced after the fusion of a spermatium with the trichogyne of an archicarp, as described in the case of Collema (page 94). In most cases no sexual process has been observed.

The hymenial layer of the fructification of the form into which a basidiomycete enters has basidia and paraphyses like those of the ordinary Basidiomycetes.

The mode of growth of the lichen is in most forms determined by the fungus constituent, the algæ dividing and multiplying as the thallus extends. In some cases the algæ are more prominent, the fungus-hyphæ being very fine and delicate. The algæ occupy nearly the whole substance of the branches, and are covered by a gelatinous envelope derived from their cell-walls. In this the delicate fungus-hyphæ ramify.

Fig. 856.

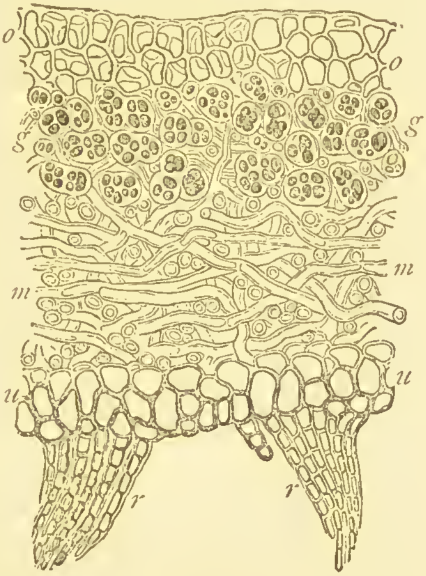


Fig. 856 Transverse section of the thallus of *Sticta fuliginosa* (×300). *o.* Cortical layer of the upper side; *u*, of the under side. *r*, *r*, Attaching fibres. *m.* Medullary layer, consisting of fungal hyphæ. *g.* The algal cells.

The lichens reproduce themselves vegetatively by forming peculiar gemmæ termed *soredia*. These are composed of a small bundle of fungal filaments investing a few algal cells. They are cast off from the surface of the thallus and speedily reproduce it.

The Algæ which take part in the composition of lichens are usually very simple unicellular or filamentous forms, such as Nostoc, Chroococcus, Scytonema, Protococcus, &c. Rarely higher forms are found, such as members of the Coleochætaceæ.

CHAPTER IV.

GROUP II.

BRYOPHYTA.

THE plants of this group show a great advance in complexity of structure when compared with the Thallophyta. There is a well-marked antithetical alternation of generations, the gametophyte giving rise to the sporophyte uniformly as the result of the fertilisation of a female sexual cell. The spore on germinating always produces a gametophyte.

The gametophyte is the body which is usually termed the plant, the sporophyte is a stalked spherical or ovoid structure which arises upon it and never has a separate existence. The gametophyte shows considerable morphological differentiation; in the lower forms it is a thallus; in some a little higher it is a thalloid stem bearing a few rudimentary leaves; in the highest forms it is a leafy shoot. There are never any true roots, but a number of unicellular rhizoids, or of multicellular filaments, attach it to the soil. It always contains chlorophyll, the arrangement of the plastids presenting considerable variety.

The gametophyte consists of two parts. When the spore germinates it does not at once produce what we recognise as the plant, but gives rise to a structure called the *protonema* (*fig.* 857), which is in some cases a flattened plate-like body and in others a much-branched filament. Upon this protonema the plant arises usually as a lateral bud, which grows up into the form of the adult gametophyte.

The protonema contains chloroplastids in all its cells; it exists usually for a short time only, though in some of the Mosses it persists for a long period. Generally in the Hepaticæ the protonema gives rise to only one plant; in the Mosses, on the other hand, several may spring from it.

The anatomical differentiation of the gametophyte is not very great. The tissue is nearly all parenchymatous, but in some of the Mosses there is in the axis an indication of vascular tissue occupying the centre. This is, however, very rudimentary, true vessels or tracheïds never being found. A similar tissue occurs in the midribs of the leaves in some species. The epidermis is not completely differentiated and bears no stomata. The apical meristem is usually well defined, and consists in some cases of a single apical cell and in others of a group of such cells.

The sexual organs, borne only on the gametophyte, are of two kinds, *antheridia* giving rise to *antherozoids* or *spermatozoids*, and *archegonia*, containing each an *oosphere*. In most cases they arise in groups, often on special receptacles, or at the apices of leafy shoots. They are generally surrounded by some arrangement for protection, being either embedded in the tissue of the receptacle or furnished with foliaceous investments. The antheridia are club-shaped, spherical, or ovoid bodies, furnished with a stalk (*figs.* 858 and 865). They consist of a wall composed of a single layer of cells, and a mass of cells in the interior, each of which gives rise to a spirally coiled body furnished with two long cilia and known as a *spermatozoid* or *antherozoid*. The cells in which the latter bodies are developed are known as *mother cells*. When the antheridium is mature it bursts, and the mother cells escape, the spermatozoids being discharged from them later (*fig.* 859, A). Each antheridium produces a large number of the latter.

FIG. 857.

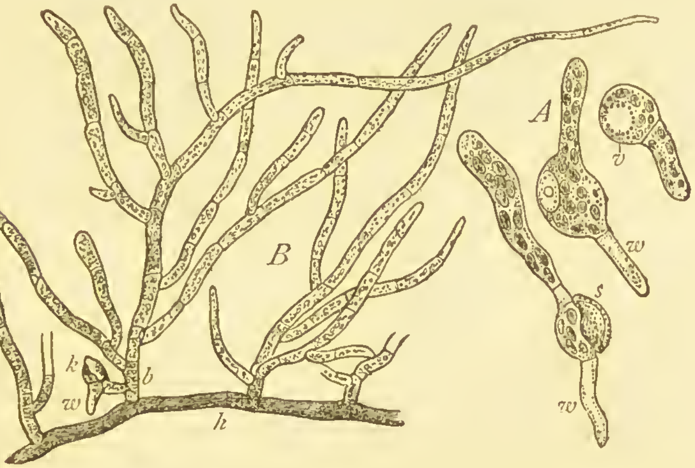


Fig. 857. Protonema of Moss. *A*. Early stages of germination of spore. *B*. Developed protonema, on which young bud, *k w*, is formed, which will give rise to the moss plant. After Sachs.

The archegonia are flask-shaped bodies, provided with a short stalk and a long neck (*fig.* 866). The swollen portion at the base is the *venter* and contains the oosphere. The wall of the venter is continued upwards to form the neck. Within the wall, extending down the neck and into the venter is a single row of cells, the lowest one of which gives rise to the oosphere, and the remainder are known as the neck-canal-cells. Before forming the oosphere the lowest cell divides into two, of which the upper one is the smaller, and is known as the *ventral canal-cell.* The other one is the oosphere. The terminal cells of the neck separate when the archegonium is mature. The neck-canal-cells and the ventral canal-cell become converted into a kind of

FIG. 858.

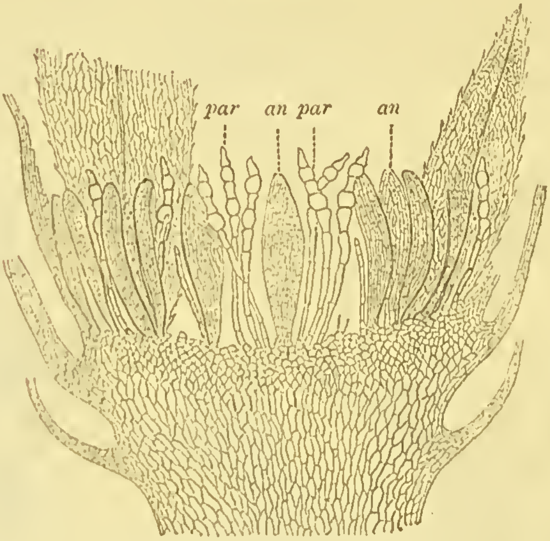


FIG. 859.

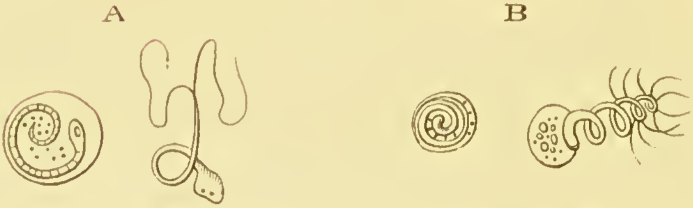


Fig. 858. Vertical section through apex of male plant of a Moss, *Mnium hornum* (×40). *an.* Antheridia. *par.* Paraphyses.——*Fig.* 859. A. Antherozoids of Moss (×1200). B. Antherozoids of Fern (×700).

mucilaginous material, so that a spermatozoid can make its way down the neck to the oosphere, and, fusing with it, form the zygote or oospore.

The process of fertilisation is rendered possible by the fact that the surface of the plant is generally moistened by rain or dew. The liberated spermatozoid can make its way about in this moisture, swimming by means of its cilia. It appears to be attracted to the archegonium by the mucilaginous contents of the neck, which escapes when the lid-cells of the neck separate. This is said to contain a sugar, possibly cane-sugar, which is the attractive matter.

The oospore germinates at once, without becoming detached from the archegonium. It divides into two cells by a wall, known as the basal wall, forming an epibasal and a hypobasal half. The former gives rise, by further segmentation and division, to the body of the sporophyte, which is a capsule known as the *sporogonium*. The hypobasal cell usually in a similar way develops a structure known as the *foot*, which attaches the young sporogonium to the gametophyte. There is no continuity of tissue, however, between the two; the foot forms a means of attachment only, and serves to absorb nutriment from the gametophyte. In some forms the foot is not developed from the hypobasal cell, which does not divide at all, but remains rudimentary and functionless. Then a foot is derived from the lower part of the mass which is of epibasal origin. In the Riccieæ there is no foot, but both hypobasal and epibasal cells go to form the capsule. In some cases the capsule is developed only from the upper part of the epibasal mass, the lower part forming a more or less elongated seta or stalk.

As this development takes place from the oospore *in situ*, the growth of the sporophyte is attended by changes which take place in the archegonium. The venter of the latter grows as the sporophyte increases and forms an investment to it which, in the forms with sessile sporogonia, remains surrounding it till the spores are ripe. In the stalked forms it is ruptured by the elongation of the seta, and in the Mosses is carried up on the top of the capsule. This investment is known as the *calyptra*. When it is ruptured the part which remains at the base of the seta and forms a sheath to it, is known as the *vaginula*.

The body of the sporogonium soon shows a differentiation into an external portion known as the *amphithecium* and an internal part called the *endothecium*. In the higher forms an air space arises in the inner part of the amphithecium, which is bridged over by strands of cells. The amphitheeium gives rise generally only to the wall of the capsule, but in one or two families the sporogenous tissue is derived from it. In most cases the latter springs from either the whole or part of the endothecium. In the latter case a central portion of the tissue remains sterile and constitutes the *columella*.

The spores are derived from a mass of cells which are early marked off by the richness and granularity of their contents. These are known as the *archesporium*. In most cases in the Hepaticæ the whole of the endothecium becomes sporogenous; in the remainder (*Anthocerotaceæ*) the archesporium is the inner layer of the amphithecium. In the Mosses it is generally the outer layer of the endothecium; the Sphagnaceæ forming an exception, behaving like Anthoceros. In the genus *Archidium* of the Mosses the sporogenous tissue is found in the endothecium, but is not regularly arranged as in the other groups.

In the Hepaticæ the archesporium consists of cells which are of two kinds, some sporogenous, giving rise to spores, others sterile, generally becoming elongated and narrow, with a peculiar spiral thickening on their walls. These are known as *elaters*; they help to disperse the spores when the capsule opens, becoming suddenly elongated by virtue of the longitudinal extension of the spiral band. Elaters are absent from one family of the Hepaticæ, the *Ricciceæ*, where all the archesporial cells are sporogenous.

The sporogenous tissue of the archesporium consists of a number of cells with granular contents. Sometimes a good deal of cell-division goes on in this area, sometimes not. Eventually what are known as the *mother cells of the spores* constitute its substance. In each of these four spores are produced by free cell-formation in the way already described. They are situated at points corresponding to the four angles of a tetrahedron, and the groups are often spoken of as *tetrads*. Before the spores are fully developed the mother cells separate from each other, and later the spores themselves are set free from the latter, each being now a mass of protoplasm, covered by a cell-wall of two coats which the latter has secreted round itself.

The spores are liberated by the rupture of the capsule or its decay. When rupture takes place it may be irregular, or by splitting into valves, or by the separation of the upper portion in the form of a lid known as the *operculum*.

The sporogonium thus formed shows a certain morphological differentiation, there being in the segmentation of the zygote an indication of the formation of root and shoot, the latter being the result of the development of the epibasal cell, while the root is represented by the body developed from the hypobasal one (see vol. i. p. 11). The shoot is not differentiated morphologically, always being a thallus and never bearing leaves.

Besides the regular sexual reproduction, leading to antithetical alternation of generations as described, the gametophyte may and often does reproduce itself vegetatively, giving rise to a kind of homologous alternation also. It rarely possesses the power of forming gonidia, which we have seen to be so common among the Thallophytes. It often, however, produces *gemmæ* upon some part of its surface. These gemmæ have a very varied distribution; in many Hepaticæ they arise in cup-shaped receptacles upon the upper surface (*figs.* 860 and 865); in others they are developed upon the leaves; in the Mosses a collection of them is sometimes found upon a long stalk (*Aulocomnion*) (*fig.* 861), or they may occur upon the axis or on the rhizoids. They are generally flattened masses of cells, sometimes with definite growing points. Most mosses can put out protonemal filaments from various parts of their surface, which can develop new plants as did the original protonema. Frequently branches are separated from the plant by the dying away of the older tissue at their bases, and these then become fresh plants.

Fig. 860.

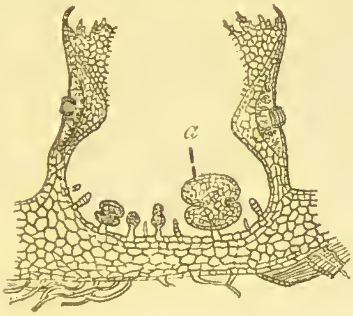


Fig. 861.

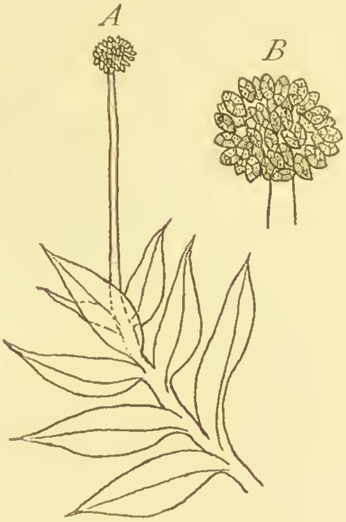


Fig. 860. Section of cup-shaped receptacle of *Marchantia*, in which gemmæ, *a*, are being developed.——*Fig.* 861. *A. Aulocomnion androgynum*, showing gemmæ borne upon a long stalk. *B.* Collection of gemmæ magnified.

The Bryophyta include the two classes of the *Hepaticæ* or Liverworts, and the *Musci* or true Mosses.

CLASS IV.—HEPATICÆ (LIVERWORTS).

The differences which are met with between this group and the succeeding one chiefly concern the sporophyte. In the Hepaticæ the sporogonium is never set free from the calyptra till the spores are mature; the calyptra is never carried up as a cap to the sporogonium, but the whole of it remains as a vaginula; there is no gradual elongation of the seta. Except in the Anthocerotaceæ there is no columella in the sporogonium, but the whole of the endothecium becomes the archesporium; except in the Riccieæ sterile cells, generally elaters, are developed as well as spores from the archesporial tissue. The vegetative body is less differentiated anatomically than in the Mosses; there is never any vascular tissue indicated in either sporophyte or gametophyte, nor are stomata present in the epidermis of the former, except in Anthoceros.

There are two types of structure found in the group, in one of which the gametophyte is a thallus or thalloid shoot, in the other it is a leafy shoot. These are spoken of as *thallose* and *foliose* respectively. The former include the two orders Marchantiaceæ and Anthocerotaceæ, the latter are found among the Jungermanniaceæ.

THALLOSE LIVERWORTS.—One of the commonest representatives of the thallose liverworts is *Marchantia polymorpha*, the structure of which may be described in detail. From the spore there is developed a small protonema, which, at first filamentous, expands into a flat cellular plate, on which the body of the plant arises by budding. This has a thick creeping dichotomously branching thalloid stem, from the under side of which a number of rhizoids are given off. It also bears on the lower surface two rows of scaly leaves. The upper surface is somewhat corrugated and bears the sexual organs on special receptacles or gametophores; it also gives rise to a number of circular gemmæ-cups or *cupules*, in which the gemmæ arise from superficial cells (*fig.* 865).

The shoot is dorsiventral, the two surfaces showing marked differences in structure.

The upper surface is marked by somewhat indistinct lines, dividing it into a number of lozenge-shaped or rhomboidal areas, in the centre of each of which is a peculiar opening or pit leading into an air-chamber, which is bounded above by a single layer of cells forming the upper epidermis. From the bottom of this cavity arise a number of short filaments which contain numerous chloroplastids (*fig.* 862). The pit or opening is bounded by a number of tiers of cells, constituting what is sometimes called a *stoma*. It is not, however, a true stoma, as the cells have no power of opening or closing the aperture (*fig.* 863).

Below the layer of air-chambers the thallus consists of several layers of elongated thin-walled or but slightly thickened parenchymatous cells which have no intercellular spaces and which contain few chloroplastids. These cells become smaller and more compact as the ventral surface is approached. The outer layer of these is not especially marked off as a lower epidermis.

FIG. 862.

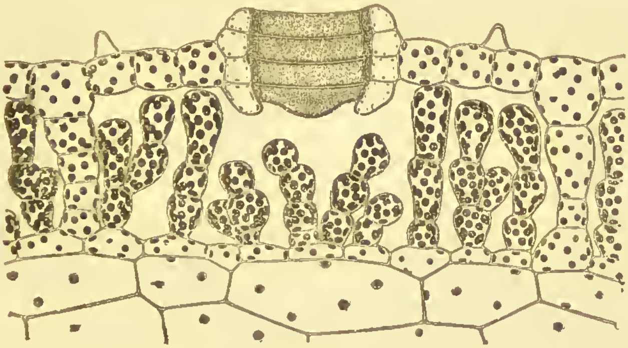


Fig. 862. Section through an air-chamber of the surface of the thallus of *Marchantia*, showing chlorophyllaceous tissue and stoma. After Kny.

The rhizoids are long and unbranched filaments. Some of them contain peculiar peg-like projections of cellulose in their interior.

The thallus grows by the divisions of a group of apical cells which are situated in a depression at the anterior end. The branching is truly dichotomous.

The cupules bearing the gemmæ spring from the air-chamber layer, of which they are outgrowths. Their walls show similar air-cavities to those of the rest of the shoot (*fig.* 864). The gemmæ themselves arise from single cells of the epidermis of the base of the cupule, which elongate upwards and segment into two, the lower of which forms a stalk, while the upper develops into a somewhat circular plate, with a conspicuous notch or depression on each side. In these depressions the growing points are formed. Each gemma is several cells thick in the centre, but the layers thin out towards the margin, where it is only one cell thick. When it falls to the ground after liberation from the cup, the lower surface puts out rhizoids and the upper takes on the structure already described. There is at first no difference in structure between the two sides; whichever happens to come in contact with the ground becomes the ventral one. The gemma contains chloroplastids.

Marchantia is a diœcious form; some shoots give rise to antheridia, others to archegonia.

Both these organs are borne on special gametophores, which spring from the upper surface of the thallus. The antheridiophore (*fig.* 865, *d*) is a thick fleshy stalk which spreads out at the summit into a somewhat flattened circular disc, which is lobed at its margins. The disc has several growing points, each producing antheridia in acropetal succession, which are seated in depressions on its upper surface. The surface of the disc contains air-chambers like those of the rest of the thallus. The antheridia have the structure already described; the depressions in which they are seated are flask-shaped, and only communicate with the exterior by a narrow canal.

FIG. 863.

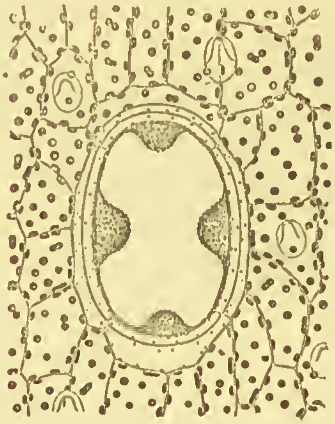


FIG. 864.

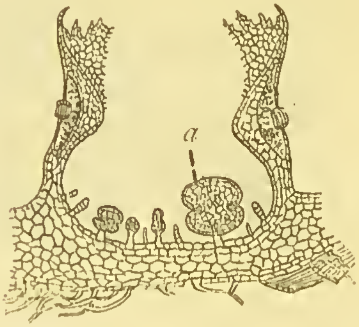


Fig. 863. Surface view of the so-called stoma of *Marchantia* (×250). After Kny.——*Fig.* 864. Receptacle of *Marchantia* with gemmæ, *a*.

The archegoniophore is somewhat more complex. Like the antheridiophore, it is a long stalked body, crowned by a disc. The latter is not a flattened structure, but consists of eight arms or branches radiating from the centre of the stalk, somewhat like the ribs of an umbrella. The archegonia are developed on its under surface in the angles between the ribs and the stalk (*figs.* 866 and 867).

The elongation of the stalk is proceeding while the arche-

FIG. 865.

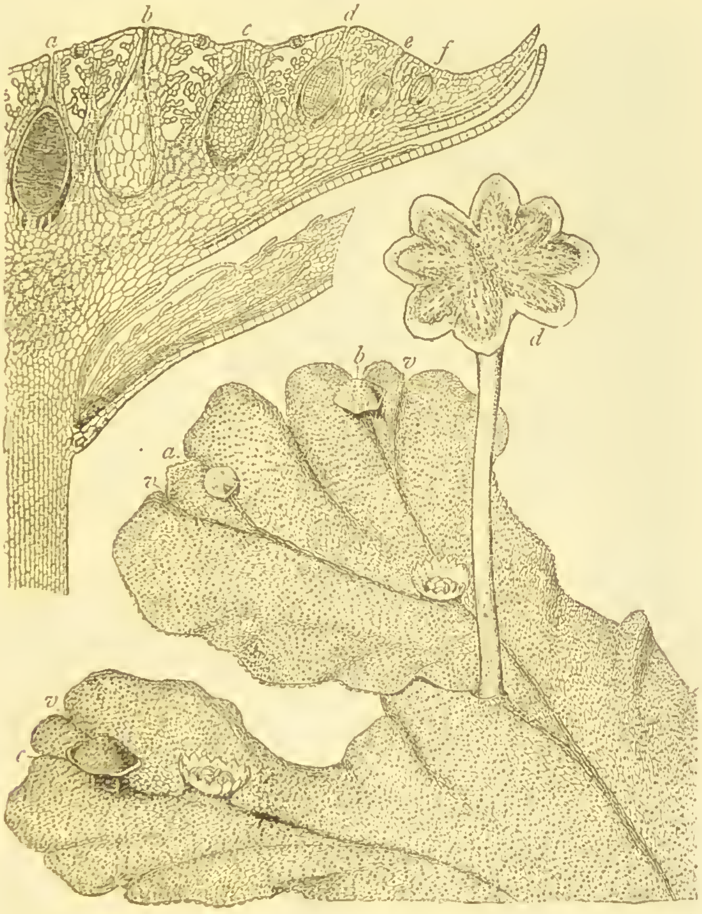


Fig. 865. Thallus of *Marchantia* with gemmæ cups, *b*, and antheridiophore, *d*. The upper figure is a section through part of *d*. *a*, *b*, *c*, *d*, *e*, *f*. Antheridia in depressions in successive stages of development. After Kny.

gonia are being developed, and they do not spread out freely till fertilisation is effected.

The structure of the archegonia has been already described. They are not embedded in the tissue of the receptacle as are the antheridia, but they are invested by a peculiar outgrowth from it, called the *perichætium*, which often surrounds a group of them. This springs from the air-chamber layer, but thins out as it grows, forming a membranous structure which is very much dissected or lobed. Besides this perichætium, another membrane, the *perigynium*, grows up from the base of each archegonium itself, surrounding it as a kind of open sac as it approaches maturity.

Fig. 866.

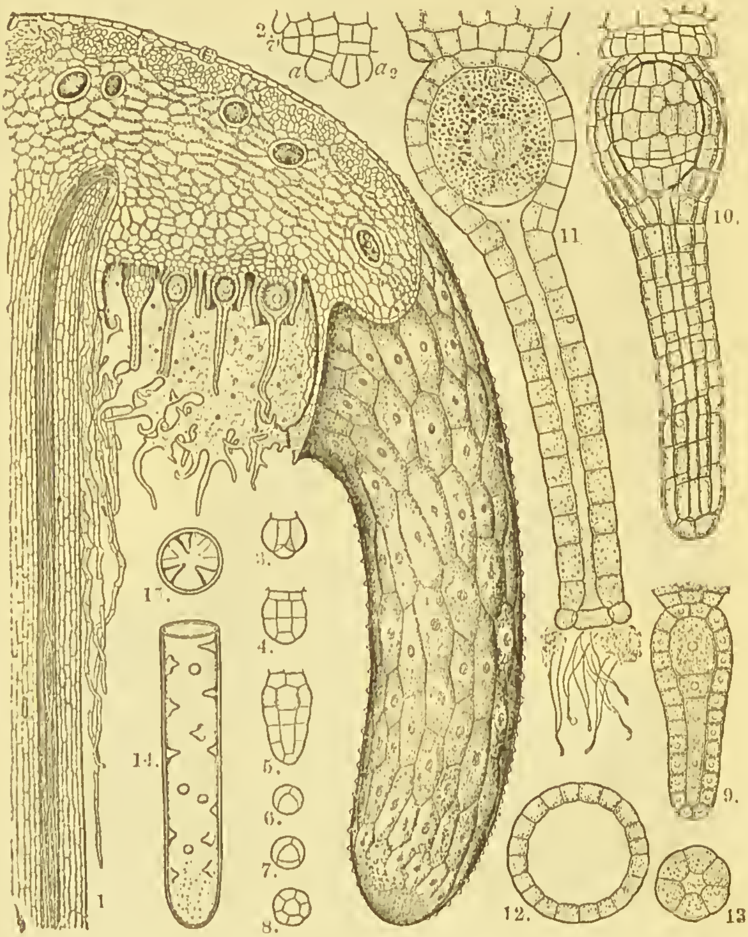


Fig. 866. Archegoniophore of *Marchantia*, bearing archegonia on under surface. 2, 3, 4, 5, 9, 10, 11. Successive stages in development of archegonia. 14. Root-hair with characteristic thickening on the walls. After Kny.

Both the antheridiophore and the archegoniophore are compound, being composed of two coherent branches, the ventral surfaces of which are consequently internal. From these ventral surfaces rhizoids are originated which may be found, on section of the structure, passing down the centre of the stalk.

The sporophyte or sporogonium arises in the manner described for the whole group. After the division of the oospore

Fig. 867.

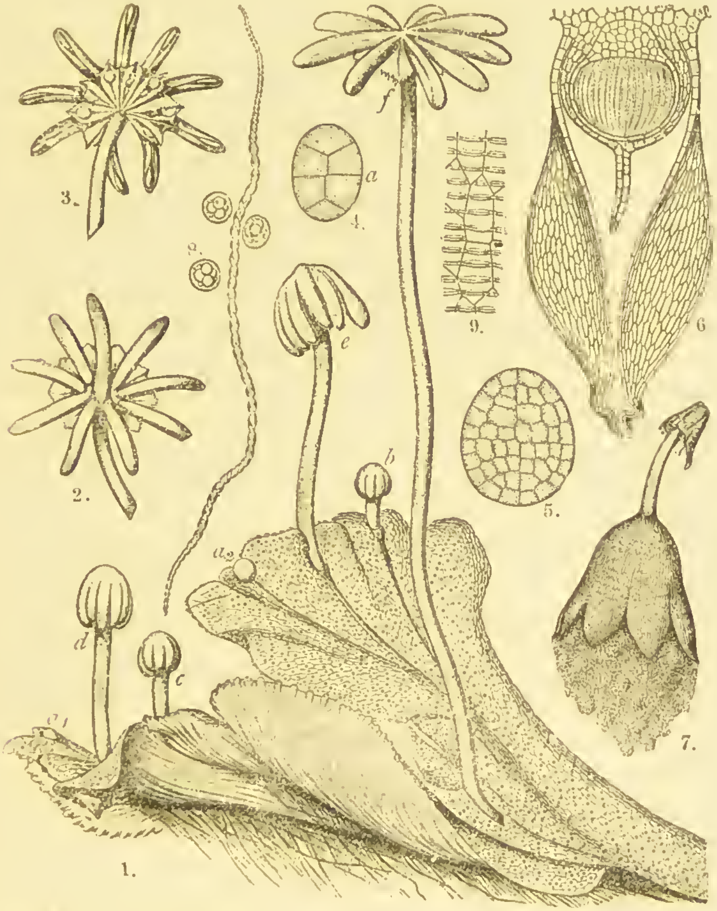


Fig. 867. 1. Thallus of *Marchantia* bearing archegoniophores. *a, b, c, d, f.* Successive stages in their development. 2, 3. Upper and under appearances of archegoniophore when the sporogonia are mature. 6. Young sporogonium. 7. Adult sporogonium dehiscing and discharging the spores. 8. Elater, with mother cells of spores adhering to it. After Kny.

into epibasal and hypobasal segments, two other walls are formed at right angles to each other and to the basal wall, dividing the oospore into octants. The hypobasal octants give rise to a somewhat bulky foot, while the epibasal ones develop the capsule. All the cells of the endothecium go to form the archesporium, which gives rise to the spore mother cells and to the elaters. The latter are very hygroscopic, and assist in the disseminating of the spores when the capsule opens. When mature, the capsule is forced out of the calyptra by the elongation of a short seta, or stalk, developed from the hypobasal region by intercalary growth. It then opens longitudinally by a number of fissures, and the spores are liberated.

A simpler type of thallose liverwort is represented by *Pellia*, which occurs nearly as plentifully as *Marchantia*, growing usually in shady damp positions, though it is not unknown on sandy soil. It is a good deal like *Marchantia* in the form of its thallus, but it differs considerably in its structure. The special air-chambers so characteristic of *Marchantia* are not found in *Pellia*, whose thallus consists of parenchymatous tissue only. The chloroplasts are present chiefly in the upper layers. The epidermis is only slightly differentiated from the rest of the parenchyma, but is slightly cuticularised. The growth and branching of the thallus occur in the same ways as in the case of *Marchantia*.

The reproductive structures again are simpler. There are no special receptacles, but the antheridia and archegonia are developed upon the upper surface of the thallus. The former appear first, the archegonia later. Both organs arise upon the same thallus. They have the same general structure as in *Marchantia*.

The capsule or sporophyte of *Pellia* is a stalked body, the seta often being two inches or more in length. The archegonial wall is ruptured before the great extension of the stalk takes place, so that the capsule is not covered by a calyptra. The capsule contains both spores and elaters, the latter radiating from the centre of its base, and being more regularly distributed than those of *Marchantia*.

In some Riccias antheridia and archegonia occur in the same sorus.

In *Anthoceros* and *Blasia*, chiefly on the under surface of the shoots, various cavities occur which are filled with mucilage. In these, quantities of the Alga *Nostoc* live symbiotically. The cavities become irregularly septate in consequence of filamentous outgrowths from the cells of their walls.

Anthoceros is peculiar also in the fact that its chloroplastids contain pyrenoids like those of the Algæ.

The sporogonium of *Anthoceros* is remarkable in two respects.

Its endothecium is sterile and forms a columella, while the archesporium is developed from the inner layers of the amphithecium. It continues to elongate by basal growth, forming a long pod-like body which dehisces from the apex downwards by two valves.

FOLIOSE LIVERWORTS.—The foliose liverworts have a dorsiventral axis bearing leaves which are generally of two kinds. The ventral surface produces a row of very rudimentary ones, which are known as *amphigastria*, while on the lateral faces are developed the ordinary foliage leaves. Rhizoids also spring from the ventral side, and mucilaginous secreting hairs occur near the growing point.

The growth in length is carried out by a single apical cell, which is in most cases two-sided, and hence cuts off two series of segments. In some forms the apical cell is a three-sided pyramid. Each segment produces a leaf and also contributes to the increase of size of the stem. The branching of the axis is usually monopodial.

Vegetative reproduction is carried out by means of gemmæ, as in *Marchantia*, but the gemmæ are, as a rule, simpler in structure, often being composed of only one or two cells. They arise either from the margins of the leaves or from the axis near its apex.

The antheridia are stalked, somewhat globular, bodies which are not sunk in the tissue as in *Marchantia*, but arise singly or in groups on the shoot near its apex, in the axils of the leaves.

The archegonia are developed later, sometimes from the same shoot as the antheridia. They are sometimes solitary, sometimes in groups, and are surrounded by a kind of involucre formed either by the cohesion together of the youngest whorl of leaves, or by a perichætial outgrowth resembling that of *Marchantia*. They are produced directly from the apical cell or its youngest segments, so that they are terminal in their position. Usually each archegonium is protected also by a perigynium.

The histological differentiation of the shoot is very slight. The stem possesses an axial strand of cells which have thin walls, while the cortex is made up of fairly thick-walled cells. There is no indication of anything like vascular tissue. The leaves are simple plates of cells of uniform substance, being only one cell thick.

The sporophyte is mainly derived from the epibasal cell of the first division of the oospore, the hypobasal one often not developing at all, but remaining in an atrophied condition at the base of the stalk of the capsule. The epibasal mass then can be differentiated into the capsule and a bulky stalk or seta, the lower end of which swells and forms a false foot (*fig.* 868). The archesporium is co-extensive with the endothecium and produces spores and sterile cells, usually elaters. When it is mature the capsule dehisces, in some cases regularly by valves, in others irregularly.

FIG. 868.

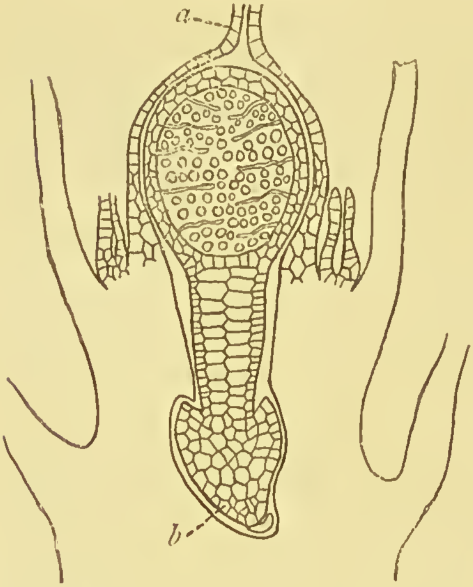


Fig. 868. Sporogonium of *Jungermannia*. *a*. Calyptra. *b*. False foot. After Sachs.

A calyptra is formed during the growth of the embryo or sporophyte, much as in *Marchantia*. When the capsule is mature, a rapid growth of the short seta ruptures it at the apex, and the sporogonium is exposed. It then dehisces as described.

According to Goebel, there is a possible link between the Hepaticæ and the Chlorophyceæ in the genus *Aneura*, from the thallus of which certain cells are liberated which may be compared with the zoogonidia of the latter. On liberation each divides into two cells, and ultimately gives rise to a new gametophyte. They differ from zoogonidia in not possessing cilia.

CLASS V.—MUSCI (MOSSES).

In the group of the true mosses a still further advance is seen, especially in the direction of anatomical differentiation. The gametophyte is always foliose, and bears well-developed rhizoids. The sporogonium escapes from the calyptra before the spores are mature; it never contains elaters, and always possesses a well-defined columella. The plants are of small size, and grow upon the earth, rocks, trees, or old walls; some are saprophytic, growing on decaying wood, &c. A few are aquatic.

FIG. 869.

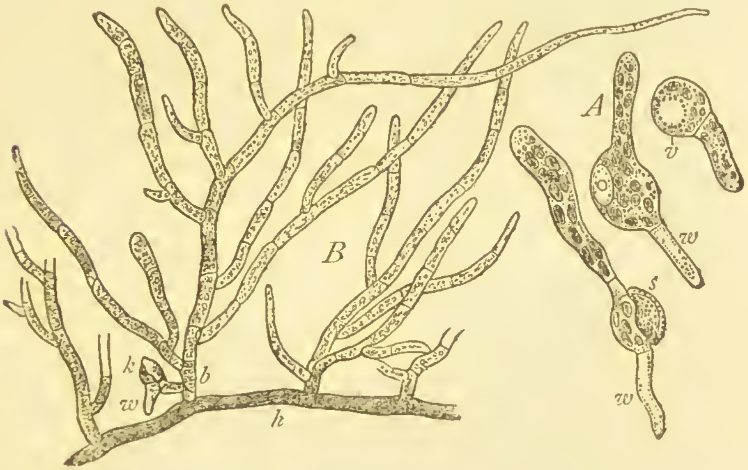


Fig. 869. Protonema of Moss. *A*. Early stages of germination of spore. *B*. Developed protonema on which young bud, *k w*, is formed, which will give rise to the moss plant. After Sachs.

The protonema is in most cases a filamentous structure, copiously branched. The septa are usually arranged obliquely across the filament. Generally part of it ramifies below the surface of the soil and is colourless, while the remainder contains chloroplastids. Each filament grows by segmentation of a single terminal or apical cell.

The shoot is rarely dorsiventral as in the Liverworts. It grows by means of an apical cell, which is usually three-sided, and gives rise by its segmentation to three rows of leaves. It is frequently branched, the branches arising, not in the axils of the leaves, as in the Phanerogams, but either beside or below them.

The branching is usually monopodial, but sometimes cymose. From the base of the shoots a number of rhizoids spring and affix it to the substratum. The plant is not supplied with water exclusively by these, the leaves having the power of absorbing liquid.

The shoot is differentiated into stem and leaves. The anatomical structure of the stem is interesting as giving the first indication of a central stele, which is, however, very rudimentary. The outer layers form a cortex of somewhat prosenchymatous cells with thick walls. This gradually passes into a thin-walled parenchyma. In some forms the axis is occupied by a strand of small rather thin-walled cells or tracheïds (*fig.* 870). In others there is a rudimentary vascular stele consisting of a number of cells, which are partly parenchymatous and partly prosenchymatous. The latter cells are tracheïds, as are those of the first type; true vessels are never developed. This central group of cells, partly thin-walled, partly thick-walled, corresponds to the xylem of the stele. It is often surrounded by elongated thin-walled cells, which correspond to phloëm. There is no pericycle and no endodermis.

Fig. 870.

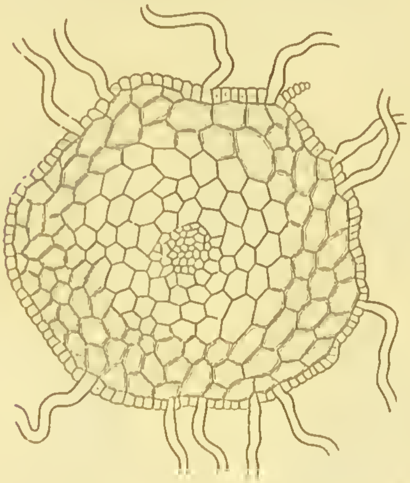


Fig. 870. Section of stem of gametophyte of Moss, showing central strand of thin-walled small cells, surrounded by large-celled cortex and epidermis. After Sachs.

The leaves which are developed on the stem are simple in most mosses, consisting often of a single layer of cells. Some forms are furnished with a midrib, chiefly composed of thick-walled cells almost prosenchymatous in shape. In some the midrib is penetrated by rudimentary vascular strands, which enter the stem and join its axial stele. The cells of the leaf all contain chloroplastids.

The leaves of the bog-mosses (*Sphagnum*) show a peculiarity in containing cells of two kinds (*fig.* 871); some are large, broad and almost lozenge-shaped, empty of contents, and marked by curious spiral thickenings; others, which form a network between the large ones, are small and tubular and contain chloroplastids.

FIG. 871.

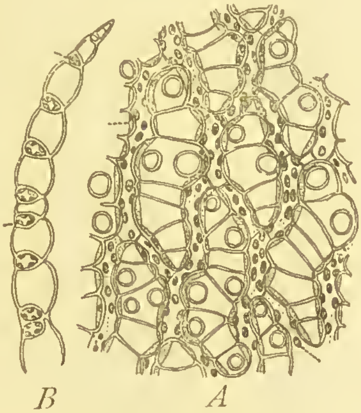


Fig. 871. Leaf of *Sphagnum*. *A*. Surface view. *B*. Section.

The antheridia and archegonia are usually borne amid clusters of leaves at the apex of a shoot. Most generally there are several together, though this is not always the case. Sometimes a shoot bears only antheridia, sometimes only archegonia, sometimes archegonia in the centre of the sorus or collection, and antheridia around the periphery. We may thus have monœcious, diœcious, or hermaphrodite arrangement.

The sorus is invested with leaves of rather different character from the ordinary foliage leaves; the innermost of them at any rate growing up in a sort of perichætial fashion round the base of the capsule as it begins to develop. There is no special perichætium produced as in the liverworts.

FIG. 872.

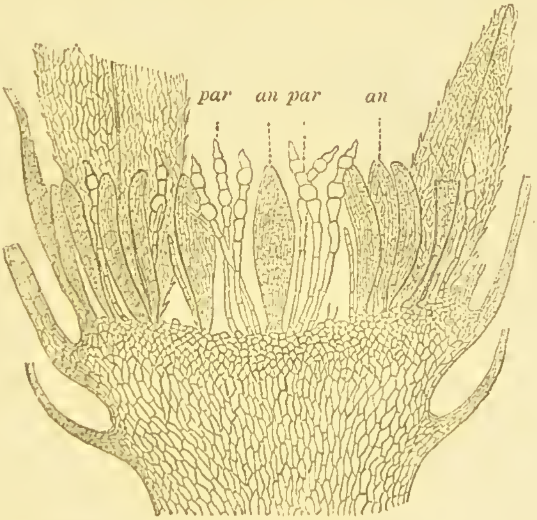


Fig. 872. Vertical section through apex of male plant of a Moss, *Mnium hornum* (×40). *an*. Antheridia. *par*. Paraphyses.

Among the sexual organs are developed hairs of peculiar form known as *paraphyses*. These are multicellular, and often terminate in a globular head. They are singular in that their cells often contain chloroplastids.

FIG. 873.

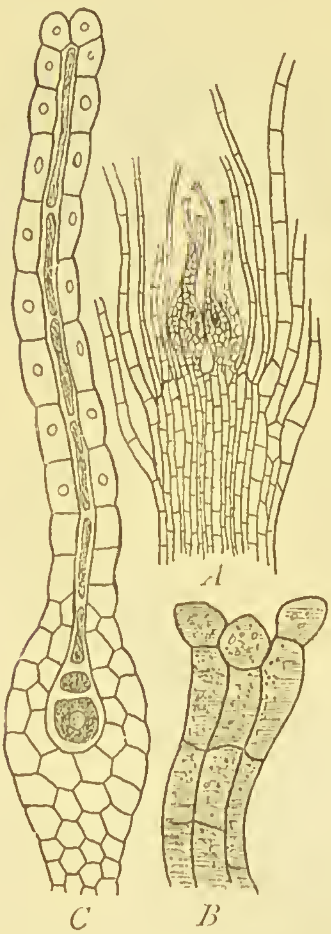


Fig. 873. *A*. Apex of shoot of *Funaria* with two archegonia. *B*. Neck of archegonium, showing mode of separation of the cells. *C*. Immature archegonium. After Sachs.

The antheridia differ but little from those of the Hepaticæ; they are club-shaped or rounded bodies, mounted on short stalks, and consist of a wall surrounding a cavity in which are the antherozoids. They open in the mosses by splitting across the apex. The mother cells of the antherozoids escape before emitting the antherozoids. They are attached to each other by a sort of intercellular mucilage derived from the cell-walls. This, however, dissolves as soon as it comes into contact with water.

The archegonia have the same general structure as those in the preceding group (*fig.* 873). There is a body or venter, and a long generally twisted neck. The body or venter is usually thicker than in the liverworts, and consists of two layers of cells. It contains, as in other cases, an oosphere, while the neck is filled with mucilage derived from the disintegration of its canal-cells and of the ventral canal-cell cut off in the formation of the oosphere.

The vegetative reproduction of the gametophyte is very varied. The chief feature of it is the ease with which almost any part of the plant can produce protonemal filaments, even rhizoids doing so if exposed to light in a moist atmosphere. Similar outgrowths may spring from the leaves, or from the summits of the shoots which produce the reproductive organs.

Besides these protonemal outgrowths leaf-buds are sometimes formed, which become detached and grow at once into moss plants. They may arise on different parts of the plant, but seem to be most easily developed upon the rhizoids. Some mosses multiply by the separation of branches, or by the production of stolons.

Definite gemmæ like those in the Marchantiaceæ are also of frequent occurrence. They are stalked flattened bodies of more or less circular shape, and consist of a single layer of cells. Many of them are developed together at the end of a long supporting axis in *Aulocomnion androgynum* (*fig.* 874); in *Tetraphis pellucida* they are produced in a terminal cup, which is composed of several leaves. When detached from the plant and transported to moist soil they germinate, putting out a protonema, on which a new gametophyte arises by the formation of a lateral bud.

It is in the structure and development of the sporogonium that the mosses chiefly show a great advance upon the liverworts. A sporogonium typical of most mosses is that of *Funaria hygrometrica*, the structure of which may be examined in some detail.

The first division of the oosphere is, as before, caused by the appearance of the basal wall, dividing it into epibasal and hypobasal segments. The latter takes little part in the subsequent development, not dividing more than once in most cases. In some of the less highly organised mosses, such as *Sphagnum*, it gives rise to a foot, but this absorbing organ in the higher forms is developed from the end of the seta.

The segmentation of the epibasal cell into octants is unusual. Instead, by a succession of oblique divisions, an apical cell is soon produced, and by the repeated division of this the embryo grows. When it has reached a fair degree of development, being fusiform in shape, the upper end swells to form the *capsule* or *theca*, and the remainder continues elongating to form the stalk or *seta*. As it elongates it ruptures the tissue of the archegonial wall which still surrounds it. This breaks across irregularly, and the withered neck with part of the venter-wall is carried up by the elongating stalk and is recognised as an easily detachable cap over the capsule. It is called the *calyptra* (*fig.* 875, *B o*).

When the capsule has become slightly swollen the tissue of its substance differentiates into amphithecium and endothecium. An air space or cavity arises in the former, which extends in a cylindrical fashion all round the capsule, being crossed by strands or filaments of cells, forming a number of bridles.

The endothecium gives rise to the archesporium, its outer layer being transformed into it. The remainder of its tissue, consisting of large cells, forms the columella. The archesporium is cylindrical and does not extend across either top or bottom of the columella. The walls of the capsule contain chloroplasts in the cells of their inner layers.

The arrangements for causing and regulating the escape of the spores from the capsule are the *operculum* and the *peristome*. The former is the apical portion of the amphithecium. It is detached from the rest of the capsule by the swelling of the walls of a ring of epidermal cells, the *annulus*, situated at the point of rupture. This swelling causes the separation of the operculum from the rest of the theca, and the lid falls off.

Fig. 874.

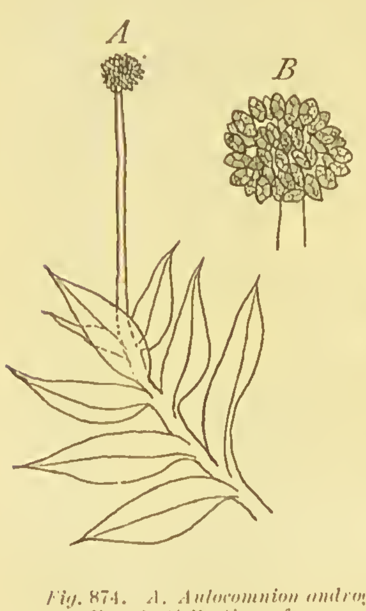


Fig. 875.

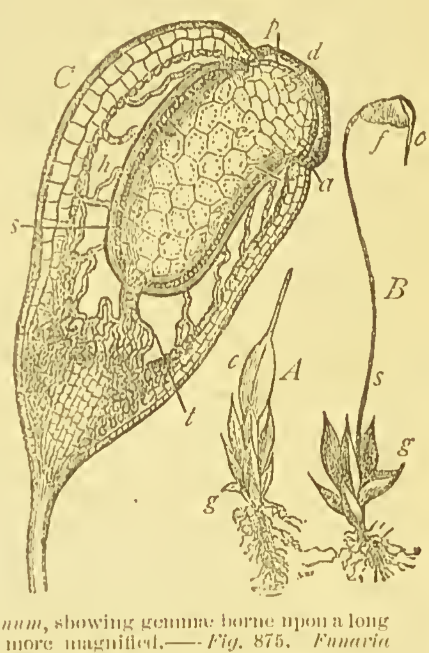


Fig. 874. *A*. *Aulocomnion androgynum*, showing gemmæ borne upon a long stalk. *B*. Collection of gemmae more magnified.——*Fig.* 875. *Funaria hygrometrica*. *A*. Young sporogonium. *c*. Capsule. *B*. Adult condition of the gametophyte. *s*. Stalk or seta of the sporogonium. *f*. Capsule or theca. *o*. Calyptra. *C*. Section of a sporogonium ×80. *d*. Operculum. *p*. Peristome. *h*. Air-space. *s*. Sporogenous layer. (After Prantl.)

The peristome is also developed from the amphithecium just below the operculum, so that when the latter falls off it forms a kind of fringe round the margin of the opening. The cells of the innermost amphithecial layer, situated just above the termination of the cylindrical air-chamber, undergo thickening and cuticularisation on their external and internal faces. The lateral and part of the transverse walls connecting the others remain unchanged. These, as the peristome dries, break away from the cuticularised walls, and the latter separate longitudinally into several strips (*fig.* 876). There are thus two rows of cuticularised membranous teeth formed, which, so long as the operculum is in position, curve over and meet at a point in the centre. The outer ones are known as the *teeth* of the peristome, the inner ones, which are less strongly thickened, are called *cilia*. The number of teeth varies from 4 to 64, according to the number of longitudinal divisions of the cells. When the operculum falls off, these teeth uncoil in virtue of their elasticity and remain as a kind of fringe round the opening.

FIG. 876.

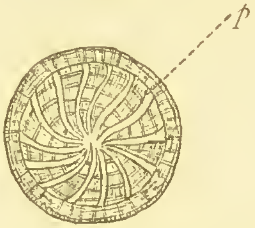


Fig. 876. Surface view of peristome, *p*, of *Funaria*.

The lower portion of the capsule below the air-space is slightly dilated, forming a mass of cells known as the *apophysis*. This is furnished with stomata, and contains a large amount of assimilating tissue.

There is a good deal of variety in the formation of the peristome in different genera. In some, as *Gymnostomum*, none is developed. In *Tetraphis* the layer giving rise to it is two cells in thickness, and all their walls become thickened, forming a plate of tissue. When this is released it splits into four valves or segments. In *Polytrichum* the development is different. The teeth are formed not of simple pieces of membrane, but of bundles of thick prosenchymatous cells. A plate of cells unites the top of the teeth and remains after dehiscence of the theca as a structure called the *epiphragm*.

As the spores mature, the rest of the contents of the capsule dry up and shrink; when they are ripe nearly everything else has disappeared, so that the spores lie loose in the cavity of the theca.

Some species show important differences of structure from the type of *Funaria*. In *Sphagnum* the archesporium, which is developed from the inner layer of the amphithecium, is a hemispherical or dome-shaped band extending across the top of the capsule and covering the columella. In *Polytrichum* a second air-chamber is formed in the endothecium on the inner side of the archesporium. In a few mosses there is no operculum.

The advance in histological differentiation which marks the gametophyte is also seen in the structure of the sporophyte

There is a well-marked epidermis, which in the region of the apophysis is furnished with rudimentary stomata. The seta contains a strand of pseudo-vascular tissue similar to that described as occurring in the stem. The tissue of the sporogonium also contains chloroplastids.

Fig. 877.

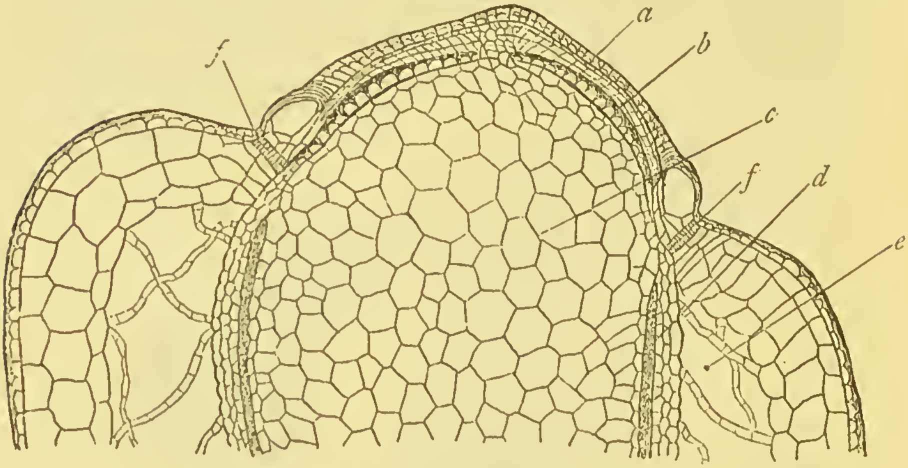


Fig. 877. Upper portion of capsule (sporogonium) of *Funaria* ×50. *a.* Operculum. *b.* Peristome. *c.* Columella. *d.* Sporogenous tissue. *e.* Air-chamber. *f.* Cells forming the rim of the capsule after the operculum has been detached. The cells just above these form the annulus.

The phenomenon of *apospory*, which is not uncommon in the next group, the Pteridophyta, occurs also in some mosses. Under favourable conditions some of the cells of the sporogonium put out protonemal filaments which give rise by budding to new gametophytes. We get thus the formation of the latter from the sporophyte without the production of spores.

CHAPTER V.

GROUP III.

PTERIDOPHYTA.

THIS group, which is sometimes known as the group of the Vascular Cryptogams, includes the Ferns, the Equisetums or Horsetails, and the Lycopodinæ or Club-mosses. They are called *Vascular* Cryptogams, to indicate that their tissues contain well-differentiated vascular structures, which we have seen to be almost entirely unrepresented in the preceding two groups. The life history embraces two phases, as in the case of the Bryophyta, but the order of their greater prominence is reversed. The gametophyte is small, cellular, and usually of very short duration; the sporophyte forms what is commonly called 'the plant,' and may persist for many years. It shows considerable morphological and histological differentiation.

Comparing the group with that of the Bryophyta we note especially the retrogression in size of the gametophyte, and the great advance made by the sporophyte. Further, that the sporophyte does not remain all its life parasitic on the gametophyte, but that it develops roots and leaves, and soon becomes independent of the latter, which usually perishes as soon as the sporophyte becomes well established. The latter generally persists many years, producing its spores annually.

In describing the forms which are included in the group, it is well to begin with the sporophyte on account of this predominance.

It shows considerable morphological differentiation, possessing, with few exceptions, root and shoot, the latter consisting of stem and leaves. The stem is often of considerable size; its growth may be sub-aerial, but it frequently takes the form of a rhizome.

The leaves are of very various sizes; in the Ferns as a rule they are large and compound; in the Club-mosses much smaller and more numerous; in the Horsetails reduced to scales closely surrounding the stem. They are of two kinds; some are ordinary foliage or scale leaves; others bear sporangia, and are known as sporophylls, as in the higher plants. In the Ferns there is usually no difference between the two, but in the other groups the sporophylls are often much modified. In the Equisetinæ and some of the Lycopodinæ they are collected together at the apices of special shoots, forming cones or flowers.

The sporophylls bear the sporangia usually in clusters, known as sori, which may be exposed to the air, or variously covered in for purposes of protection. In some cases the sporangia arise directly from the stem in the axil of the sporophyll. In the Ferns and Horsetails the sporangia are on the under or dorsal surface; in the Club-mosses on the upper one.

The primary roots are shortlived, soon being replaced by adventitious secondary ones. *Salvinia* has no primary or secondary roots, nor, so far as we know, have some species of the isosporous ferns and some of the club-mosses.

A peculiar feature makes its appearance in the Pteridophyta, which persists throughout all the higher plants. This is the production by the sporophyte of two kinds of spore, each of which gives rise to its appropriate gametophyte. The two kinds of spore differ from each other chiefly in size, some, called *microspores*, being very small, and others, *megaspores*, much larger. Each is produced in its appropriate sporangium, so that we distinguish *micro-* and *megasporangia*. The peculiarity of producing both kinds is called *heterospory*; we speak thus of *isosporous* and *heterosporous* Vascular Cryptogams.

In some cases all the sporangia of a sorus are closely attached together as if coherent. They are so developed, never being free from each other. The resulting body appears like a multilocular sporangium, but it is better to regard it as compound and call it a *synangium*.

A similar multilocular appearance is afforded by the sporangia of *Isoëtes*, but in this case it is due to bands of the archesporial tissue becoming sterile, and crossing the sporangium in the form of a number of trabeculæ.

Sporangia are classed in two categories, according to the manner of their development. In some plants, *e.g.* in many ferns, they arise each from a single superficial cell. These are known as *leptosporangiate* forms. In others, as in the *Marattias* and *Isoëtes*, the sporangia arise from a group of cells of the superficial and sometimes deeper layers as well. These forms are called *eusporangiate*.

The anatomical differentiation of the sporophyte shows a great advance on that of the sporogonium of the Bryophyta. The epidermal and cortical or fundamental tissue systems are clearly distinguishable, and the axis is either mono-, schizo- or polystelic. The stele consists of xylem and phloëm, in vascular bundles, with circumferential pericycle in most cases. There is often a very marked development of sclerenchyma either in bands or patches. The leaves range from very simple structures to others almost as well differentiated as the leaves of Phanerogams; but their mesophyll is not so well divided into palisade and spongy parenchyma, and the epidermal cells contain chloroplastids.

Fig. 878.

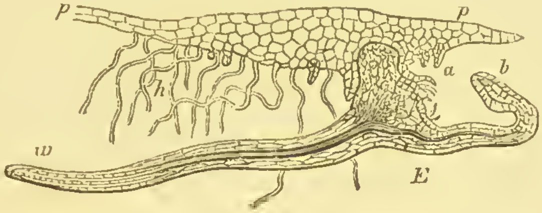


Fig. 878. Section through prothallium, *p p*, and young Fern-plant. *E*. The latter attached to the former by the foot. *a*. Archegonia of the prothallium. *h*. Root-hairs of same. After Sachs.

Fig. 879.

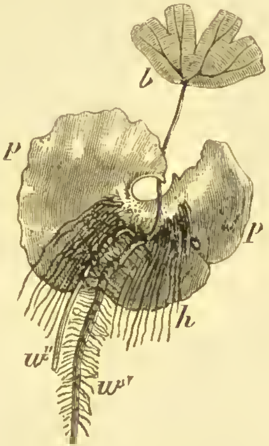


Fig. 879. Prothallium, *p p*, of *Adiantum Capillus-Veneris* seen from below, showing the Fern-plant developed from the fertilised germ-cell of the archegonium. *b*. First frond. *w'*, *w''*. Roots. *h*. Root-hairs. After Sachs.

The growth in length of the stem, root, and leaf is usually effected by the segmentation of apical cells. In some cases, instead of a single apical cell there is a group of them, especially in the higher forms, where we have indicated an approach to the Phanerogams. Growth in thickness of the axis rarely takes place; there is, however, a modified cambium in *Isoetes* and in some of the *Ophioglossaceæ*. Some of the fossil forms of this group showed considerable cambial activity, the axis becoming of very considerable diameter.

The secondary roots are not developed from the pericycle, but from the *endodermis* of the axis; in the Horsetails from its inner layer. They thus originate in the periblem and not in the plerome.

The growth of the sporophyte from the oospore or zygote shows considerable variety. Epibasal and hypobasal segments are produced, as in the Bryophyta, by the formation of a basal wall. In the Ferns and Horsetails this is followed by segmentation into octants. From the epibasal octants the stem and either one or two primary leaves or cotyledons are then produced, while from the hypobasal ones proceed the primary root and a foot which, as in the Bryophytes, serves to attach the sporophyte to the tissue of the gametophyte (*figs.* 878 and 879). The foot is in this group a transitory structure, which perishes as soon as the sporophyte is capable of an independent existence. In the Club-mosses the hypobasal segment gives rise to a *suspensor*, as it does in Angiosperms (page 198). This is only composed of a single cell, or a chain of a few cells in length.

FIG. 880.

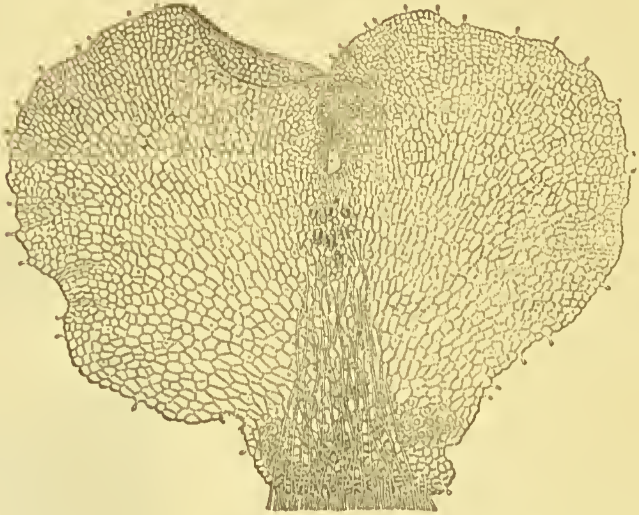


Fig. 880. Prothallium (gametophyte) of Fern. After Kny.

The gametophyte arises from the germination of the spore, in most cases becoming free from it (*fig.* 880), but in certain cases remaining partly or almost entirely in its cavity (*fig.* 881). In the former case it is usually a small thallus composed only of cells and containing chloroplastids. Its morphological character is, however, varied; it may be a filamentous much-branched body, somewhat recalling a protonema, or it may be tuberous and fleshy (*fig.* 915, *p*), when it is developed underground and contains no chlorophyll. It is always known as the *prothallium.*

In the heterosporous forms there are two kinds of prothallia formed, one from the microspore, and the other from the megaspore. In neither case do we get the prothallium entirely set free from the spore. They are not very strongly developed, only sufficiently so indeed to permit of the production of the sexual organs. The prothallium from the microspore gives rise to antheridia; that from the megaspore to archegonia. In some of the isosporous forms the prothallia, which are all alike as to their vegetative features, are monœcious, producing both antheridia and archegonia; in others, as in the Equisetums, they are diœcious, only bearing one or other of them.

FIG. 881.

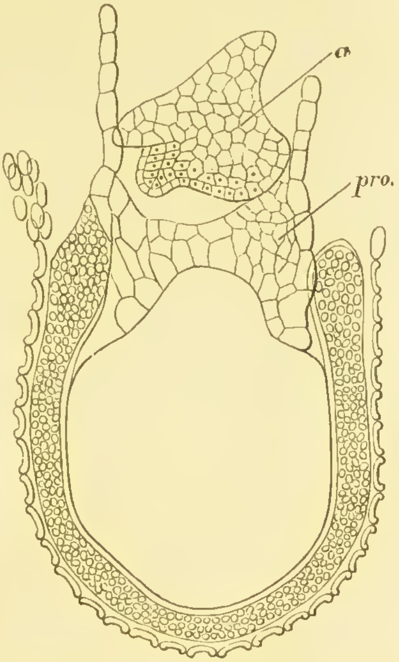


Fig. 881. Gametophyte produced by the megaspore of *Salvinia*. *pro.* Prothallium bearing *a*, young sporophyte. After Pringsheim.

The antheridia are either immersed in the substance of the prothallium, as in the tuberous forms, or project from the surface as in the flattened ones. They are always superficial in their origin, and consist of a wall of a single layer of cells, which encloses a number of spirally coiled ciliated antherozoids (*fig.* 859, B). The archegonia are also superficial, having a venter embedded in the tissue of the prothallium, and a slightly projecting neck consisting of only a small number of cells (*fig.* 895). The structure is otherwise like that of the Bryophyta. Fertilisation is effected in the same way as in the latter group. The number of archegonia produced often depends upon whether or no the oospheres of the first-formed ones become fertilised. If not, others are developed.

Vegetative reproduction of the gametophyte is not uncommon;

it takes place by means of gemmæ, or by branches which become detached. Similar reproduction of the sporophyte is brought about by the development of adventitious buds, arising on either the petiole or the lamina of the leaf in many Ferns. In a few of the Equisetums some of the underground shoots form tubers, which may remain dormant for a time and ultimately produce new stems. A similar formation is found in some of the Club-mosses.

The phenomenon of apospory is not infrequent. A specially interesting form of it occurs in *Athyrium Filix-fœmina*, where sporangia produced in the normal position grow out into prothallia instead of forming spores. In other cases the prothallia spring from the tips of the pinnæ of the leaves.

The converse process, the production of a sporophyte from the prothallium without the formation of an oospore, is occasionally seen. The prothallium in this case sometimes produces sterile archegonia; sometimes none at all. The sporophyte in either case arises as an adventitious bud upon it. This phenomenon is known as *apogamy*.

The Pteridophyta are usually arranged in three groups or series, being thought to have arisen by separate lines of development from a common Bryophytic ancestor. These three classes are the *Filicineæ*, the *Equisetineæ*, and the *Lycopodineæ*.

CLASS VI. FILICINÆ.

The usual classification of the forms included in this class is as under:—

Sub-Class ISOSPOREÆ.—One kind of spore only is produced; on germination it gives rise to a free prothallium.

Section 1. *Leptosporangiatæ.*—Each sporangium is produced from a single epidermal cell.

This section includes most of the Ferns proper.

Section 2. *Eusporangiatæ.*—Each sporangium arises from a group of epidermal cells.

This section includes the Ophioglossaceæ and Marattiaceæ.

Sub-Class HETEROSPOREÆ.—The spores are of two kinds, microspores and macrospores or megaspores. The prothallia do not become free from the spores on germination. The microspore produces a prothallium bearing an antheridium, the megaspore develops one bearing archegonia. Neither form of prothallium is ever free from the spore.

Section 1. *Leptosporangiatæ.*—Each sporangium arises from a single epidermal cell.

This section includes the water ferns, the Hydropterideæ, sometimes called the Rhizocarps.

Some botanists place a second section here to include the Isoetaceæ, which are eusporangiate. They are, however, generally included among the Lycopodinæ.

SECTION 1. ISOSPOROUS LEPTOSPORANGIATE FERNS.

The sporophyte of this group is the plant usually termed a Fern. It has generally a conspicuous body, morphologically differentiated into stem, roots, and leaves.

The stem is usually a creeping underground rhizome, though in some cases it is borne upon the surface of a tree, and in others, as in the tree ferns, it grows vertically into the air. It usually gives off a number of adventitious roots and bears a relatively few large, often pinnate, leaves. In some ferns the stem branches normally, the branch system being lateral and not dichotomous as in the lower groups; in others the branching is adventitious. The roots are also adventitious, for though a primary root is always developed it never persists in the adult fern. The adventitious roots are small and often branched, arising in great numbers from the stem or the leaf stalks. The leaves are sometimes of three kinds, the *foliage leaves*, sometimes entire, but usually much and repeatedly pinnate; the

Fig. 882.

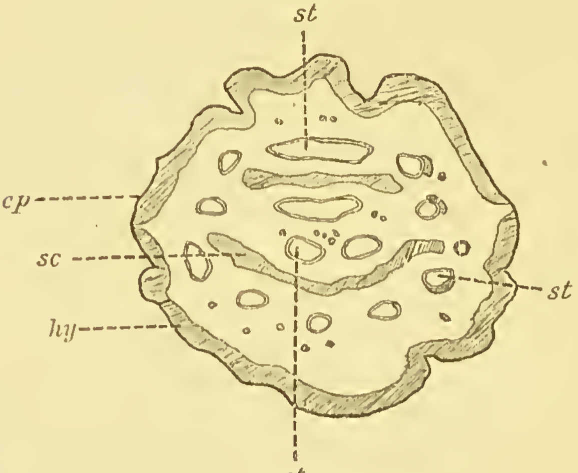


Fig. 883.

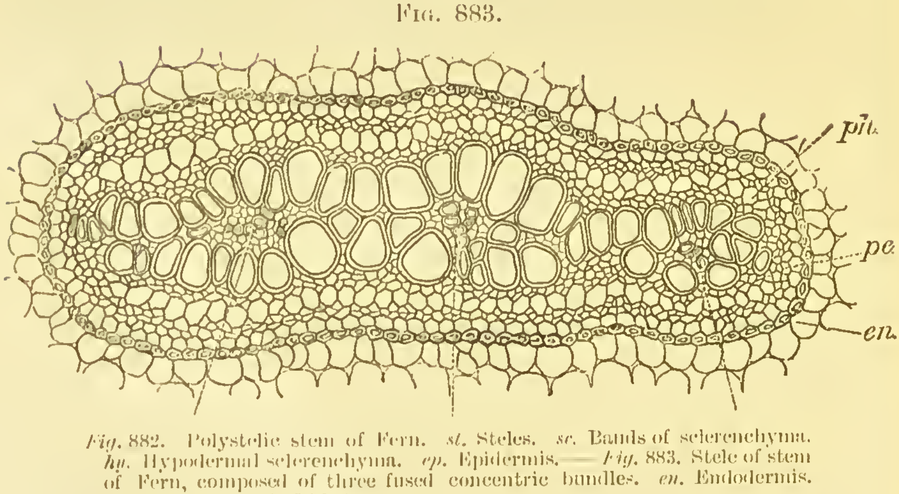


Fig. 882. Polystelic stem of Fern. *st.* Steles. *sc.* Bands of sclerenchyma. *hy.* Hypodermal sclerenchyma. *ep.* Epidermis. — *Fig.* 883. Stele of stem of Fern, composed of three fused concentric bundles. *en.* Endodermis. *pe.* Pericycle. *ph.* Phloëm.

sporophylls, which in many ferns are exactly like the foliage leaves in appearance, but in others are much modified; and *scaly leaves*, rarely found, and then only on subterranean rhizomes. The vernation of the leaves is very markedly *circinate*, the main axis and all its branches or pinnæ emerging from the earth rolled up with their lower surfaces outwards The stem and bases of the leaf stalks are furnished when young with numerous scaly hairs, called *ramenta*, which are multicellular and sometimes glandular.

The growth in length of the stem is always brought about by the divisions of a pyramidal apical cell of either two or three sides, the apex of the pyramid being directed inwards. It soon shows a differentiation into dermatogen, periblem, and plerome. At first the stem is monostelic, but this condition in most cases soon gives way to polystely, which persists throughout its length (*fig.* 882). The separate steles are usually gamodesmic, the bundles of which they are composed being completely united together, presenting the appearance of a central mass of wood with at first two or three strands of protoxylem situated near the periphery. These are formed of spirally thickened tracheïds. They are not easily distinguishable when the stem is full grown. The whole mass of wood is almost surrounded by bast, though not entirely, as the latter does not wrap round its narrow end. The whole is enclosed by a pericycle and an endodermis, the latter belonging to the fundamental tissue (*fig.* 883). The endodermis is generally two layers of cells deep, the inner one having delicate walls like those of the pericycle, but the walls of the cells of the outer layer are thickened considerably. Sometimes a stele will consist only of a single bundle (*fig.* 884), though generally fusion takes place. The steles as viewed in longitudinal section of the stem, or better, as isolated by maceration, are found to anastomose together very irregularly, forming a meshwork, from the angles of which branches go off to enter the leaves. The nature of the anastomosis is largely determined by the number and size of the leaves.

The bundles are said to be concentric. As they are usually placed two or three together in the stele and fused laterally, this is not very apparent, the whole stele seeming rather to deserve this name, the fused bast masses surrounding the fused wood masses. A single bundle, however, when found free (*fig.* 884), is seen to be concentric; and a stele is usually composed of two or more placed so close together that the bast is not developed on their contiguous faces. The lateral fusion of bast and wood of the original bundles thus gives rise to the mass of wood in the stele with its peripheral envelope of bast. The steles should perhaps be called bi-collateral rather than concentric, as the bast is not continuous round the narrow ends of the wood masses (*fig.* 883).

The monostelic arrangement persists in a few families (*Osmundaceæ*, *Hymenophyllaceæ*, &c.); the bundles in the stele are then sometimes collateral.

The pericycle is absent from the stele of some of the Polypodiaceæ, being then replaced by the inner layer of the endodermis, as in the root of *Equisetum*.

Fig. 884.

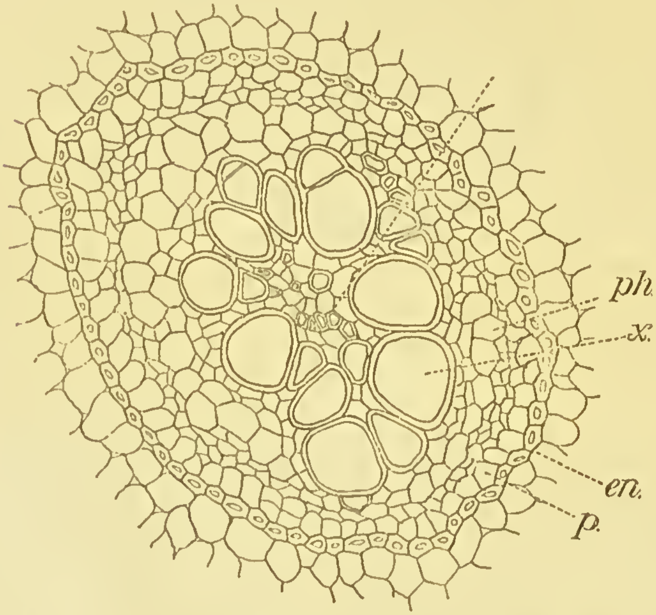


Fig. 884. Concentric bundle from Fern stem. *en.* Endodermis. *p.* Pericycle. *ph.* Phloëm. *x.* Xylem.

The stem of the fern is usually well supplied with sclerenchyma, which is developed in various forms in the ground tissue. It is often found as a strong hypodermal sheath, deep brown in colour, and consisting of several layers of cells with very greatly thickened walls. Isolated bands of greater or less extent are common in the inner part of the ground substance (*fig.* 882).

The tissue of the wood and bast is generally characteristic.

The wood is chiefly made up of large tracheïds thickened in a scalariform manner. True vessels are rare, and there is not much wood parenchyma. The sieve-tubes of the bast (*fig.* 885) are long, narrow tubes with bluntly pointed ends, and have their sieve-plates more or less regularly arranged along their whole length, being thus marked out into very characteristic areas. They have no companion-cells and no callus.

FIG. 885.

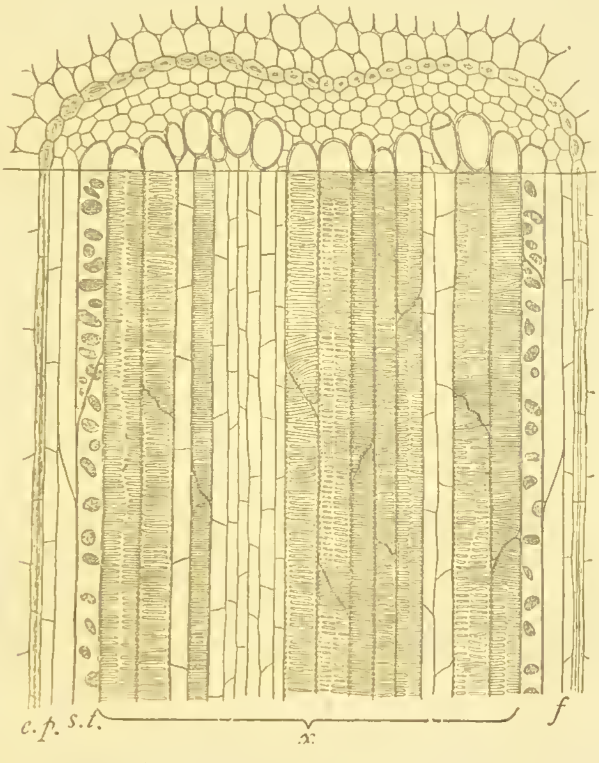


Fig. 885. Section of stele of Fern. The upper part is transverse, the lower longitudinal. *e.* Endodermis. *p.* Pericycle. *s.t.* Sieve-tube. *x.* Xylem. *f.* Fibres of bast.

Except in the monostelic stems the bundles are cauline. They are always closed, cambium not being present.

The primary root is in all cases developed, but it usually soon perishes, and its work is taken over by adventitious roots which are produced in great numbers from the stem or the leaf-stalks. Each originates in the endodermis of one of the steles, opposite to a xylem bundle. By the formation of two walls a pyramidal apical cell is cut out of one of the cells of the endodermis, and by successive divisions it gives rise to the adventitious root (*fig.* 886), which grows out through the fundamental tissue in the way already described. Occasionally, as in *Osmunda*, there may be a group of initial cells at the apex, instead of the usual pyramidal one.

The root is monostelic, the stele containing sometimes two, sometimes three bundles; the pericycle may consist of a single layer of cells or of many, and sometimes it is irregular, being one layer of cells thick in part of its course and more than one layer thick in the remainder.

When the roots branch the new root springs from the old one in the same way as the latter did from the stem.

The foliage leaves arise each from a single superficial cell of the growing point of the stem. They grow in most cases by means of a two-sided apical cell. In vernation they are strongly curled up, owing to the greater growth of the under surface. Later the region of growth changes to the upper surface and the leaves expand. In structure they resemble the leaves of Angiosperms, but the differentiation of the mesophyll into palisade and spongy parenchyma is not so well marked. The epidermal cells as a rule contain chloroplastids. The vascular cylinder is generally monostelic in the petiole, but becomes schizostelic in the leaf blade. The stele joins one of the steles of the stem as already described.

Fig. 886.

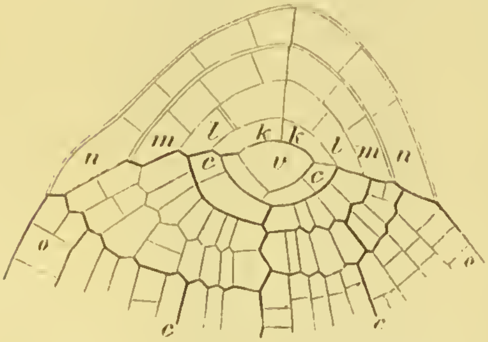


Fig. 886. Longitudinal section through root of *Pteris hastata*, showing apical region. *v*. Apical cell, from which are developed the tissue of the substance of the root, *o*, *e*, and the root-cap, *k*, *l*, *m*, *n*. After Sachs.

In some Ferns the sporangia are borne upon leaves that cannot be distinguished in appearance from ordinary foliage leaves. In others, as in *Osmunda*, *Aneimia*, &c., there are definite, specialised sporophylls. These show various shapes, the pinnæ generally being narrower than those of the foliage leaves. In the most specialised, the upper or lower branches of the phyllopodium are scarcely at all winged, the edges being covered by clusters of sporangia.

The sporangia occur usually in groups on the lower or dorsal surface of the sporophylls (*fig.* 888), or in some cases in a band along their margins, being situated on a kind of placental outgrowth. They are sometimes quite exposed to the air, sometimes partially protected by hairs or paraphyses which arise among them from the placenta. Generally, however, the sorus is more or less covered by a definite membrane called the *indusium*, which springs from the epidermis of the leaf. Where the sorus is marginal, as in *Pteris*, the edge of the leaf curves over it, forming a false indusium, which sometimes is supplemented by a kind of membrane springing from the leaf along the inner side of the sorus.

FIG. 887.

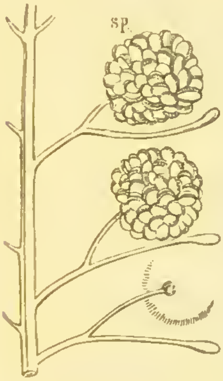


FIG. 888.

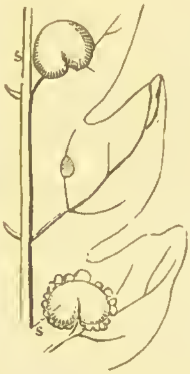


FIG. 889.

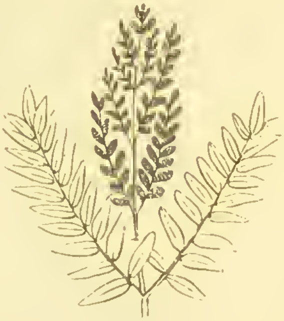


Fig. 887. A portion of a frond of the common Polypody (*Polypodium vulgare*), showing two sori springing from its veins. The sori are naked, and consist of a number of sporangia, *sp*, in which the spores are contained.——*Fig.* 888. Portion of a frond of the Male Fern (*Aspidium Filix-mas*), with two sori, *s*, *s*, covered by an indusium.——*Fig.* 889. Portion of a frond of the Royal or Flowering Fern (*Osmunda regalis*), with its sporangia or capsules arranged in a spiked manner on a branched rachis.

The sorus (*fig.* 890) consists of a number of sporangia, often mixed with a number of hairs or paraphyses, which are sometimes glandular. Each sporangium is an ovoid or globular body placed upon a long stalk. It originates from a single superficial cell of the placenta, which grows outwards and becomes divided into two. The upper one gives rise to the body of the sporangium, the lower one to the stalk. As the upper one grows, there are formed in it three oblique walls, which cut out of it a somewhat tetrahedral cell with its base uppermost.

A further wall is formed across its base, so that the structure consists of a wall and a central cell (*fig.* 891, 3). Divisions parallel to the first ones cut off from the latter four protective cells which form the *tapetum*, an investing nutritive layer, which by subsequent divisions of its cells becomes multicellular. The central cell so formed is the *archesporium*.

Changes now take place in both inner and outer parts of the growing organ. The four peripheral cells undergo repeated division by anticlinal walls, so that the outer coating of the sporangium becomes multicellular, remaining one cell thick. A special band of cells forming part of this wall, running in some cases longitudinally and in some obliquely or transversely, becomes peculiarly thickened, as in *fig.* 890, and constitutes the *annulus*. Its walls are strongly cuticularised, more so than the walls of the rest of the cells, which, however, undergo cuticularisation to some extent. The annulus in most cases does not extend completely round the sporangium, but leaves a few thin-walled cells between itself and the stalk, which cells form the *stomium*, where eventually the sporangium opens. The tapetum becomes multicellular and for a time invests the archesporium, its cells being filled with very granular protoplasm. The archesporium divides repeatedly till it generally consists of sixteen cells, the mother cells of the spores. When this stage is reached, the tapetal cells

FIG. 890.

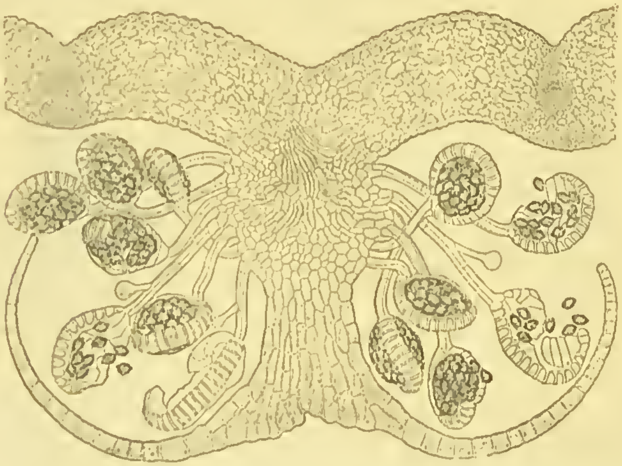


Fig. 890. Section of sorus of Fern, consisting of a number of *sporangia* borne upon a placental outgrowth from the under side of the leaf and covered by an *indusium*. Each sporangium has running nearly round it a row of thick-walled cells, the *annulus*. After Kny.

become disorganised and give rise to a mucilaginous fluid in which the archesporial mass remains. Each mother cell then divides by free-cell formation into four cells, usually but not always arranged at the four angles of a tetrahedron, so that the resulting cells are pyramidal in form. Each undergoes rejuvenescence and surrounds itself with a new cell-wall, forming a spore. The walls of the original mother cells then disintegrate as did those of the tapetum, and the spores, sixty-four in number, lie free in the cavity of the sporangium. The development is shown in *fig.* 891.

In some cases the stalks of the sporangia are not developed, so that those organs are sessile ; in others the stalk gives rise to a glandular hair (*fig.* 891, 7 *h*).

FIG. 891.

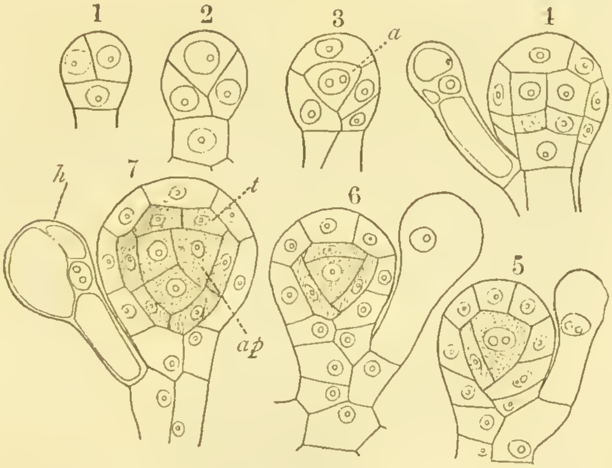


Fig. 891. Development of the sporangium of the Fern. The figures indicate the successive stages. *a.* Archesporium. *t.* Tapetum. *ap.* Sporogenous tissue. After Kny.

When the sporangium is ripe, the drying of the cells of the annulus leads to great tension in the stomium, which ruptures, and the annulus recoils with some force, scattering the spores.

In the Tree Ferns the annulus extends all round the sporangium, so that it includes the stomium.

Different genera show a certain variety in the position of the annulus, and consequently in the direction of the rupture. The dehiscence is, however, brought about in a similar manner in all.

The gametophyte in the Ferns is always a thallus, having no differentiation into members. It is known as the *prothallium*, and is usually a green flattened expansion of small size. Its cells contain chloroplastids. From the under side a number of root-hairs are developed which attach it to the soil.

Sometimes the prothallium has a central somewhat thickened portion known as the *cushion*. Sometimes it is almost filamentous, recalling the protonema of a moss.

It always becomes quite free from the spore.

On the under side of the prothallium the sexual organs are developed, the antheridia lying to the basal end and the archegonia, which are formed later, towards the anterior or apical region. In a few cases a prothallium develops only one or other of the sexual organs, but generally both are to be found in the relative positions described.

Fig. 892.

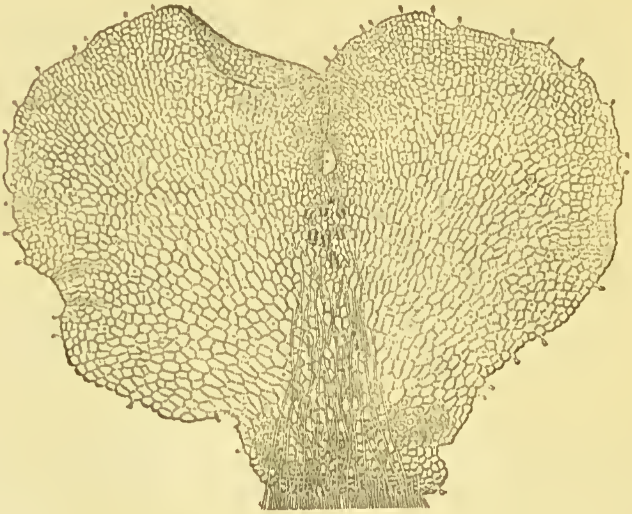


Fig. 892. Prothallium (gametophyte) of Fern. After Kny.

When the spore germinates, the outer coat ruptures and the inner one grows out into a green filament consisting of a single row of cells (*fig.* 893, 1 4). The end cell of the row soon divides longitudinally, and the plate-like prothallium becomes recognisable. The growth is soon continued by the formation of an apical cell (*fig.* 893, 5), which after a while is found to lie in a sort of notch or depression in the anterior margin.

The cushion is formed by the cells in the middle line in the anterior region then dividing in a plane parallel to the surface, so that the mass becomes several cells in thickness there. This cushion bears the archegonia and may in a way be compared to the archegoniophore of the Liverworts. The antheridia do not arise on the cushion, but towards the posterior margin.

The *antheridium* is always superficial in origin (*fig.* 894). An epidermal cell grows out and is divided into two, the upper one of which produces the organ. It divides into two cells, the lower of which forms a stalk-cell. The upper one divides repeatedly, so as to form a wall surrounding a central cell, in which the mother cells of the antherozoids are produced by repeated cell-divisions. In each mother cell a single antherozoid is produced, which is a coiled filament furnished with cilia at its anterior end (*fig.* 860, B). When the antheridium is mature it ruptures, and the mother cells, containing the antherozoids, escape, the antherozoids being liberated a little later. The whole of the protoplasm of the mother cell is not used up to form the antherozoid, so that when the latter escapes it has usually attached to it a vesicle of protoplasm, the rest of the contents of the mother cell.

Fig. 893.

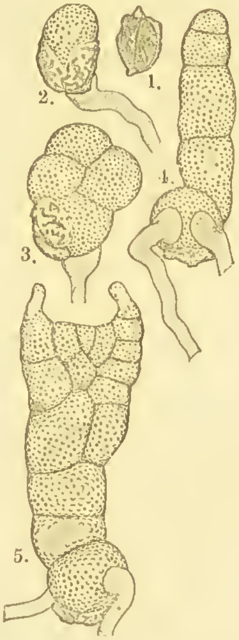


Fig. 893. 1–5. Successive stages in the early development of the prothallium (gametophyte) of the Fern. After Kny.

The development of the archegonium (*fig.* 895) is also from a superficial cell of the prothallium, which segments into two, an upper and a lower. The neck is derived from the former by a succession of divisions. It is much like the neck of the archegonium of the moss, but much shorter, consisting of only a few tiers of cells. The lower cell grows upwards into the neck, separating its cells somewhat and forming the neck-canal-cell, which remains single. The neck-canal-cell is cut off from the remainder, which then constitutes the *central cell* of the archegonium. This next cuts off a small *ventral-canal-cell*, and the remainder rounds itself off into an ovoid mass of protoplasm, which is the *oosphere*.

Later the ventral-canal-cell and the neck-canal-cell become mucilaginous, and the neck of the archegonium opens by the separation of its cells.

Fertilisation is effected by the entry of an antherozoid into the neck of the archegonium and its ultimate fusion with the oosphere at its base. The mucilaginous matter ejected from the archegonium is said to contain a substance, probably malic acid, which has an attraction for the antherozoid, enabling the latter to find its way to the canal of the neck.

Fig. 894.

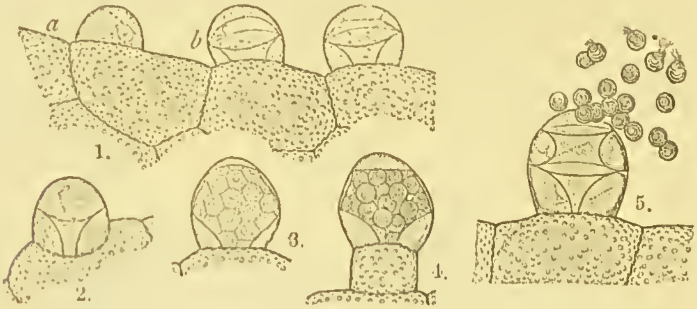


Fig. 895.

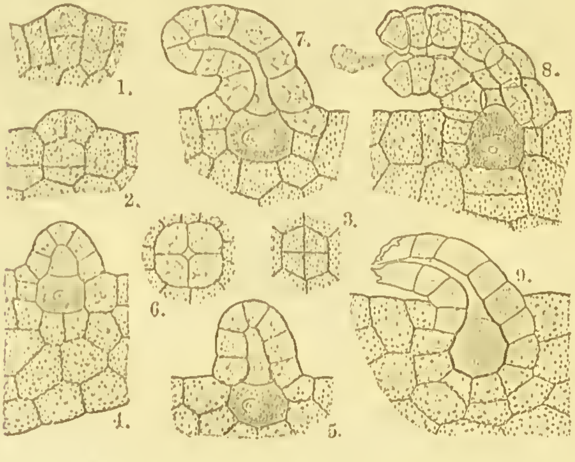


Fig. 894. 1-3. Development of the antheridium of the Fern. 5. Antherozoids escaping. After Kny.——*Fig.* 895. Development of archegonium in the Fern. The figures indicate successive stages. 3 and 6 are transverse sections of the neck in two stages. After Kny.

When fertilisation has been effected the oosphere clothes itself with a cell-wall, and becomes the *zygote*, or *oospore*. It is soon segmented into epibasal and hypobasal parts by the formation of a basal wall parallel to the axis of the archegonium. Each gives rise by further divisions to four octants. In further development the epibasal octants give origin to the stem and first leaf, or cotyledon, of the young sporophyte; the hypobasal ones form the primary root and a special organ, called the *foot*, which attaches the young fern to the prothallium, from which it draws a supply of nutrient material. The foot becomes a somewhat bulky structure and occupies the space formed by the venter of the archegonium (*fig.* 878).

The primary root soon disappears; the cotyledon also lasts but a short time, and is succeeded by the foliage leaves, arising from the stem. The foot also disappears as soon as the young fern has become capable of absorbing its nutriment from its environment independently of the gametophyte.

The prothallium seldom lives longer than is necessary to produce a single sporophyte. The sporophyte, on the contrary, may produce spores for many years, each being able to give rise to a gametophyte. Sometimes the gametophyte lives longer, in some cases for more than a year.

The vegetative reproduction of ferns occurs in both generations. The gametophyte may give rise to branches or to gemmæ, either of which can develop into prothallia. The sporophyte may produce adventitious buds, generally on the petioles of its leaves where they are below the soil.

Both apospory and apogamy may occur in this group.

SECTION 2.—ISOSPOROUS EUSPORANGIATE FERNS.

In this section are comprised two orders of Ferns, the Ophioglossaceæ and the Marattiaceæ, which have much in common with the previous group, but differ in that their sporangia are derived each from a group of superficial cells instead of from a single one.

OPHIOGLOSSACEÆ.

The affinities of the Ophioglossaceæ have lately been much discussed, and many doubts have been suggested as to their being properly included among the Ferns, certain points in their structure suggesting an affinity with the Lycopodinæ. For the present, however, it will be well to give them their old position.

The sporophyte is usually a short erect rhizome bearing a few leaves which are not circinate in vernation. Generally only one appears above ground each year. Between this leaf and the apex of the stem the rudiments of four other leaves may generally be found, so that it takes five years for a leaf to attain its full development.

The sporangia are borne upon a peculiar outgrowth from the ventral surface of the petiole of the sporophyll, which has the appearance of being branched, one branch bearing an ordinary foliage lamina and the other an elongated, sometimes branched, spike-like structure, embedded in or placed upon which are the sporangia, arranged in two rows, one on each side of its axis, or variously clustered upon its surface (*fig.* 896).

The stem is very short and presents some peculiar features in its interior. There is usually present none of the sclerenchyma, so characteristic of the Ferns; the arrangement of the vascular structures is different also, the Ophioglossaceæ being schizostelic and the bundles of the steles being collateral. Ophioglossum itself has no pericycle in its steles. The genera *Botrychium* and *Helminthostachys* possess cambium in their collateral bundles, but it does not give rise to much secondary tissue. Cork also occurs in the cortex of these stems.

FIG. 896.

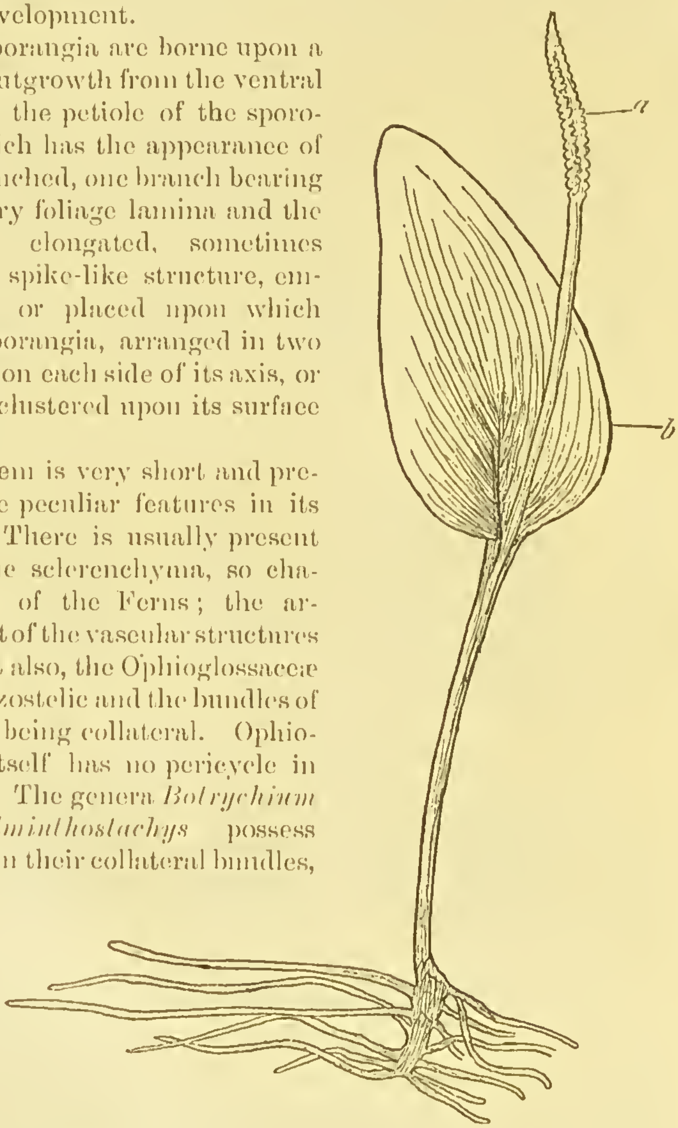


Fig 896. *Ophioglossum vulgatum*. *a*. Sporangia. *b*. Foliage leaf.

The sporangia, situated as described above, are usually quite independent of each other, not being arranged in sori. They are often embedded in the tissue of the sporophyll and open when ripe by valves or slits. Each contains numerous spores.

The gametophyte is best known in *Ophioglossum pedunculosum* and *Botrychium Lunaria.* In the former it is a tuberous body growing underground and devoid of chloroplastids. From it springs a cylindrical gametophore, which grows up through the earth and becomes green. It bears antheridia and archegonia. In the latter it is again tuberous and subterranean ; it has root-hairs, and bears antheridia and archegonia, the latter being chiefly on its lower and the former on its upper surface.

The prothallium of *Helminthostachys* has recently been discovered.

MARATTIACEÆ.

The stem of the sporophyte, as in the last case, is generally a rhizome, which is sometimes branched, and bears numerous leaves. The latter resemble those of the true Ferns, from which they differ by bearing well-marked stipules. The roots branch considerably, the branching being lateral.

FIG. 897.

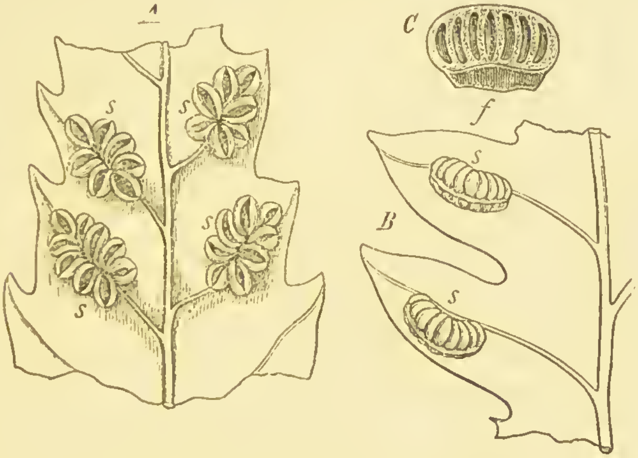


Fig. 897 Synangia, *s*, of *A*, *Angiopteris*, *B*, *Marattia* ; *C*, section of synangium of *B*. After Sachs.

The histology of the stem recalls that of the true Ferns, the arrangement of the vascular tissue being polystelic, and the bundles of the steles concentric. There is more variety in regard to the sclerenchyma, which is never very prominent and is in some cases absent. Gum passages of probably schizogenous origin are found in many parts.

The sporangia are arranged in sori, but the several sporangia of each sorus are coherent instead of being developed separately. They thus form a body, at first sight suggesting a compound sporangium. This is known as a *synangium*. They are filled with numerous spores and dehisce when ripe by a slit or an apical pore (*fig.* 897).

The gametophyte is a flattened green prothallium, much like that of the true Ferns. It has a cushion in the centre, on which both antheridia and archegonia are borne. It grows by an apical cell. The sexual organs have the same structure as in the Ferns.

SECTION 3.—HETEROSPOROUS LEPTOSPORANGIATE FERNS.

(*Rhizocarps* or *Hydropterideæ*.)

This group, which has much in common with the isosporous ferns, introduces a difference which becomes more and more important as we go higher and higher in the scale. The plants bear spores of two kinds, the *microspores* and the *macrospores* or *megaspores*. Each of these in turn produces a special form of gametophyte, and those which are derived from the megaspores never become free from the spore, being largely developed in its interior. As we pass upwards from this point this peculiarity becomes more and more marked, until we find the prothallium always completely endosporous. The great importance of this is seen in that it leads ultimately to the production of the body known as the *seed*, which is the distinguishing feature of Phanerogamic plants.

The Hydropterideæ or Rhizocarps were till comparatively recent times considered as a separate group. It is usual now to include them with the Ferns, to which they show considerable resemblance. They are all of aquatic habit, and are hence named *Hydropterideæ*. The group comprises four genera, *Salvinia*, *Azolla*, *Pilularia*, and *Marsilea*, which according to the arrangement of their sporangia are divided into the two orders *Salviniaceæ* and *Marsileaceæ*. *Salvinia* and *Azolla* float freely upon the surface of water; each has a horizontal rhizome, sometimes copiously branched. Upon the rhizome are borne numerous leaves arranged in rows, which in *Azolla* are all alike, but in *Salvinia* are of two kinds, floating and submerged.

Azolla bears numerous adventitious roots; *Salvinia* is altogether rootless.

In *Salvinia* the phyllotaxis is whorled, three leaves being produced at each node. Of these, two are broad, somewhat rugose, entire floating leaves, placed opposite each other. The third is divided into a number of filamentous branches which hang down freely into the water (*fig.* 898) and function as roots. In *Azolla* the leaves are alternate and are arranged in two rows on the upper surface of the rhizome. Each leaf is two-lobed, one lobe floating while the other is submerged. *Pilularia* and *Marsilea* have perennial rhizomes and are attached to the substratum. They are found in bogs or marshes. From the rhizome the leaves grow vertically upwards, being arranged alternately on the stem. In the former genus the leaf is unbranched and somewhat cylindrical; in the latter it is compound, bearing four leaflets at the end of a long petiole (*figs.* 901, 899).

Fig. 898.

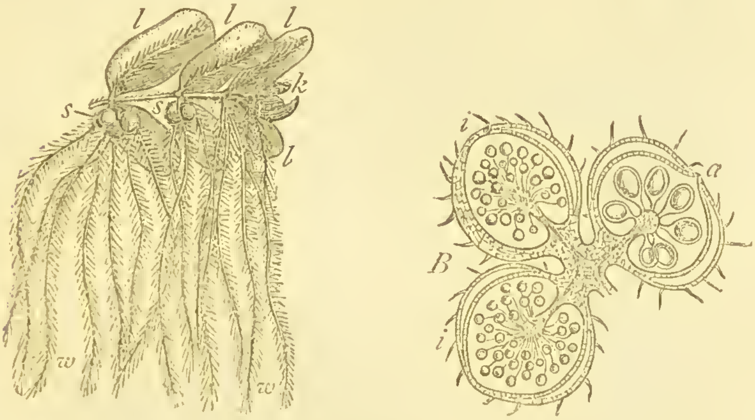


Fig. 898. Part of a plant of *Salvinia*. *l*. Floating leaves. *w*. Submerged leaves. *s*. Sori. *k*. Apex of stem. *B*. Longitudinal section through three sori of *Salvinia*. *i*, *i*. Two with microsporangia. *a*. One with megasporangia. After Sachs.

Both *Pilularia* and *Marsilea* produce adventitious roots from the rhizome.

In *Salvinia* and *Azolla* the stem is monostelic, the stele being of very small dimensions. It is not furnished with a pericycle, but is surrounded by a two-layered endodermis. In the other genera the stem is at first polystelic, but eventually becomes gamostelic from the fusion of the separate steles to form a ring (*fig.* 900). This ring encloses some fundamental tissue which simulates a pith. It can be distinguished from the latter by the fact that there is an endodermal band on both sides of the ring of bundles. The bundles are concentric in all four genera. The fundamental tissue contains large intercellular spaces or lacunæ.

The growth in length of both stem and root is carried on by means of an apical cell, which is either two-sided or tetrahedral.

A curious feature of the leaf of Azolla is the occurrence of a pit or cavity in the tissue of the dorsal lobe in which small colonies of *Nostoc* filaments are found, much as in *Anthoceros*. This is a case of symbiosis, as in the latter plant.

The two orders Salviniaceæ and Marsileaceæ differ from each other in the arrangement of their sporangia. They agree in having them placed in curious globular or ovoid bodies, which occur in *Salvinia* and *Azolla* on the submerged leaves or lobes of leaves; in *Marsilea*

FIG. 899.

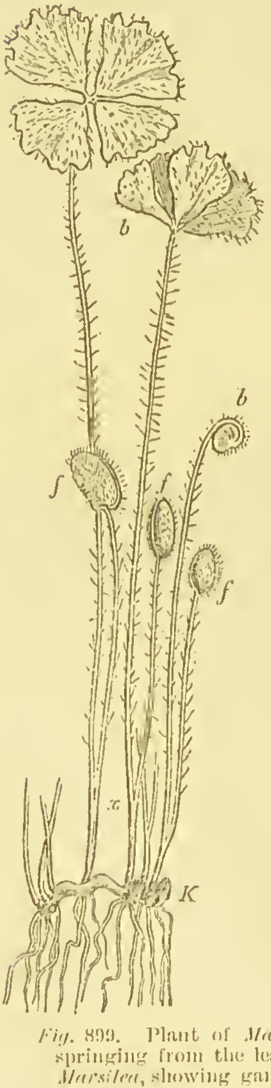


FIG. 900.

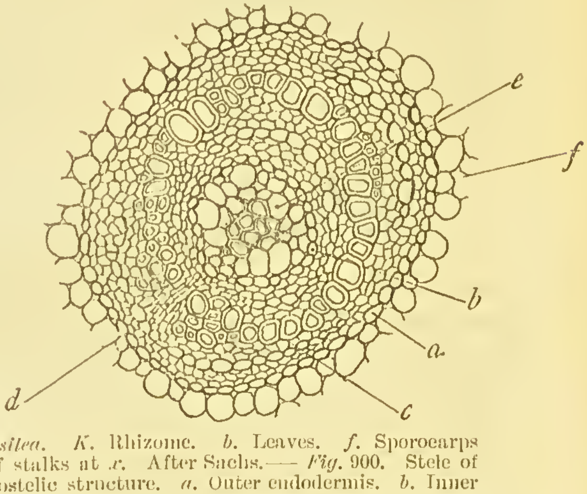


Fig. 899. Plant of *Marsilea*. *K*. Rhizome. *b*. Leaves. *f*. Sporocarps springing from the leaf stalks at *x*. After Sachs.—*Fig.* 900. Stele of *Marsilea*, showing gamostelic structure. *a*. Outer endodermis. *b*. Inner endodermis. *c*. Fused xylem bundles. *d*. A point at which the fusion does not extend to the wood. *e*. Fundamental tissue isolated by the fusion of the steles. *f*. Cortex.

on stalks springing from the petioles of the leaves much as in *Ophioglossum*; and in *Pilularia* from the rhizome on the ventral side of a leaf.

In *Salvinia* and *Azolla*, the two genera of the Salviniaceæ, the structure is a sorus of sporangia, covered in by a globular indusium, which differs from the corresponding structure in the Ferns by being composed of two layers of cells, separated in *Salvinia* by an air space (*fig.* 898, *B*), and by completely closing over the sorus. In *Azolla* the walls of the upper part of the indusium become lignified. At the base of the globular chamber so formed there is a cellular placenta, from which the sporangia spring. Each sorus consists either of microsporangia or megasporangia, but never contains both. The number of microsporangia in a sorus in both genera is considerable. The megasporangia are less numerous, the sorus of *Salvinia* containing not more than twenty-five, while that of *Azolla* contains only a single one.

Fig. 901.

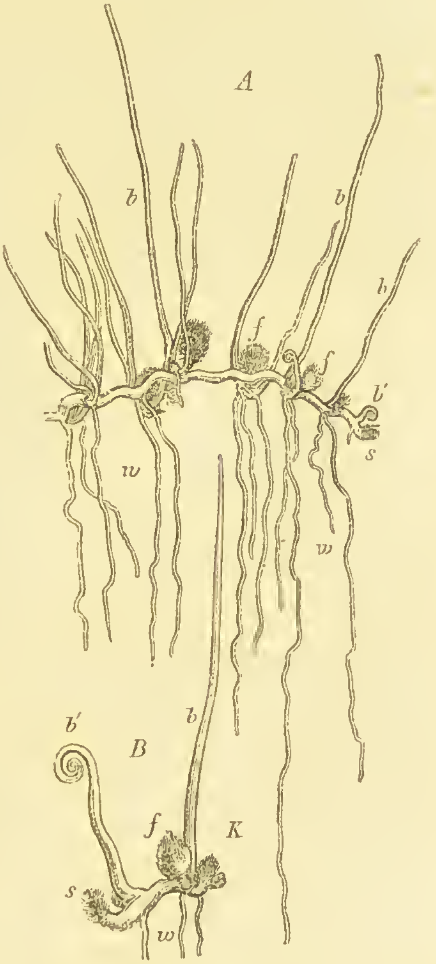


Fig. 901. *Pilularia globulifera.* *A*. Natural size. *B*. End of shoot (enlarged). *s*. Apex of stem. *b*, *b′*. Leaves. *w*. Roots. *f*. Sporocarps.

In the Marsileaceæ (*Pilularia* and *Marsilea*) the sporangia are borne in a complex structure known as a sporocarp. This is a modified leaf-branch, as shown in *fig.* 899. It is an oval or globular body with a very hard wall; its interior is divided into a number of chambers, each of which contains a sorus. The sori contain both micro- and megasporangia. In *Marsilea* there is in each a single row of the latter in the middle, and a double row of the former on each side of it. In *Pilularia* the arrangement is not so definite.

Fig. 902.

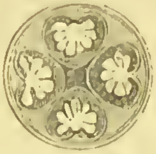


Fig. 902. Transverse section of the sporocarp of *Pilularia globulifera*. After Henfrey.

Fig. 903.

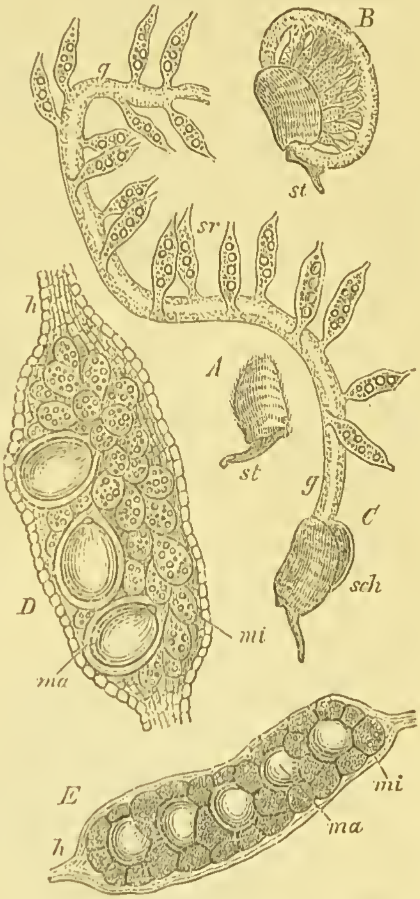


Fig. 903. *Marsilea salvatrix*. *A*. A sporocarp (natural size). *B*. A sporocarp which has burst its water and is protruding its gelatinous ring. After Hanstein. *C*. The ring ruptured and extended, showing the separated sori, *sr*. *D*. A sorus showing megasporangia and microsporangia. *E*. A sorus from a ripe sporocarp. After Sachs.

The sporocarp is made to rupture by the mucilaginous character of the internal tissue, which absorbs water and causes the wall of the sporocarp to split. In *Pilularia* the rupture begins at the apex, in *Marsilea* it takes place along the side. In the sporocarp of the latter is a band or ring of mucilaginous tissue, to which the walls of the chambers containing the sori are attached. When the sporocarp ruptures by the swelling of this ring, the latter protrudes through the opening, and still swelling drags out with it the sori in a kind of string or chain (*fig.* 903, *BC*). When free from the sporocarp the walls of the sori-chambers and those of the sporangia disintegrate, setting free the spores.

The spores in this group of plants are characteristic. Instead of possessing only two walls and lying free in the sporangia, as in almost all other cases, they either have a third coat, derived from the epiplasm of the disorganised tapetal cells, or they are by this epiplasm agglutinated together into one or more spore masses. The conditions differ in the different genera. In *Salvinia* all the microspores of a sporangium are fastened together; in *Azolla* there are from two to eight of such masses in a sporangium, each being known as a *massula*. A delicate skin surrounds each massula, and this in some species is furnished with a number of hairs bearing barbed processes, known as *glochidia*, at their free ends. In the Marsileaceæ the microspores are free from each other, but each is coated by its *epispore* or *perinium*, derived from the tapetal epiplasm.

In *Salvinia*, *Pilularia*, and *Marsilea* the megaspores are similarly invested, but each one is free. The outer layer of the epispore in the last two genera is capable of swelling enormously on being wetted, surrounding the apex of the spore with a mucilaginous coating.

In *Azolla* the epispore on the lower surface of the megaspore is developed into large spongy masses which serve as floats, enabling it to drift about after partially escaping from the sporangium. The upper surface is firmer and bears filamentous outgrowths. The apex of the spore is generally furnished with a number of delicate filaments extending between the floats. The glochidia of the massulæ of microspores generally catch in these filaments, so that the massulæ are anchored to the megaspore.

The microspores are not set free from the microsporangium in *Salvinia*, but germinate *in situ*. In *Azolla* the separate massulæ escape and float about in the water, those that have glochidia usually becoming entangled in the filaments developed from the perinium of the megaspore.

The gametophyte in this group shows considerable reduction when compared with that of the Ferns. The heterospory, as already pointed out, involves the production of two kinds of gametophyte, one from each kind of spore. We have from the microspore one that bears only male organs, *antheridia*, and from the megaspore one that bears only female organs, *archegonia*. In neither case does the gametophyte become entirely free from the spore which gives it origin; in some cases a good part of it remains enclosed within the spore.

In *Salvinia* the microspores germinate by putting out a tubular protrusion of the endospore, which pierces the mucilaginous matter in which they are embedded and makes its way through the wall of the sporangium. It then forms a septum at the end, cutting off a terminal cell which later divides into two. The tube constitutes the prothallium, and its two end cells after further divisions form a rudimentary antheridium, in which are produced four antherozoids (*fig.* 904).

When the antherozoids are mature, the antheridium ruptures as in other cases, and the antherozoids, each in its mother cell, escape into the water. Only part of the protoplasm of the mother cell is used in the formation of the antherozoid, as in the Ferns.

Azolla produces a similar male gametophyte. In the Marsileaceæ the latter is formed within the microspore. The first division of the spore produces a small basal vegetative cell and a larger apical one, which forms an antheridium. By successive divisions this comes to consist of eight cells surrounded by a parietal layer or wall. The central cells produce each four antherozoids. Throughout the group the male prothallium is destitute of chloroplastids.

FIG. 904.

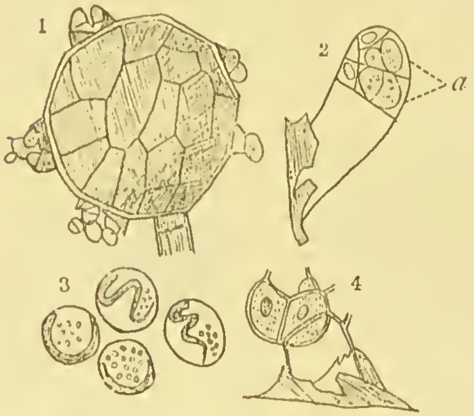


Fig. 904. Germination of microspores of *Salvinia*. After Sachs. 1. The mass of spores putting out tubular prothalli. 2. A prothallus, with antheridium, *a*. 3. Antherozoids in mother cells. 4. Ruptured antheridium.

The formation of the female prothallium is a good deal alike in all the genera, showing small differences in the extent of its protrusion from the spore, from which it is never free. The megaspore begins to germinate before its coats rupture; it first cuts off a small cell at its anterior end or apex, by a wall known as the *diaphragm*, which thus divides the spore into two. The small cell at the apex continues to divide, forming a small celled tissue which soon protrudes through the spore-coats, owing to the rupture of the latter. The emerging tissue develops chloroplastids and becomes green; it constitutes the prothallium. In *Salvinia* it is somewhat triangular in shape and bears two winged appendages (*fig.* 905). In the Marsileaceæ only a small part of it protrudes from the opening of the spore.

The lower cell takes no part in the formation of the prothallium, but remains almost unchanged, becoming filled with various reserve materials for the nutrition of the young embryo developed later on the prothallium. In *Azolla* its nucleus divides repeatedly, but no cell-walls are formed in it.

Fig. 905.

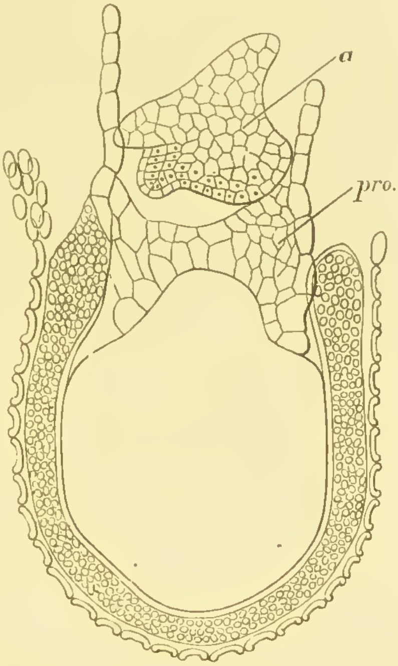


Fig. 905. Gametophyte produced by the megaspore of *Salvinia*. *pro.* Prothallium bearing *a*, young sporophyte. After Pringsheim.

The archegonia are developed at the apex of the prothallium, three being usually formed in *Salvinia*, but only one in the Marsileaceæ and *Azolla*. If none of the first formed ones become fertilised, more are developed later. The structure is similar to that of the Ferns.

In the germination of the zygote or oospore *Salvinia* shows some peculiar features. It segments into octants as in the Ferns, but all the hypobasal cells go to form the foot. No root is developed. The first leaf or cotyledon, developed from two of the epibasal cells, is of curious shape. It is known as the *scutiform leaf*. In the other three genera there are two cotyledons, stem, and root, as well as foot.

Class VII.—EQUISETINÆ.

The plants included in this class, which only includes the genus *Equisetum*, are characterised by a peculiar habit; they generally have a much-branched subterranean rhizome, from which sub-aerial shoots are given off which rise erect and may attain a height of six or seven feet. These aerial shoots are of two kinds, one purely vegetative and the other ultimately becoming terminated by a cone-like collection of sporophylls, forming a flower. The shoots are surrounded at every node by a ring of small scale-like leaves cohering together at their bases, in the axil of each of which a branch is produced, causing a succession of whorls of branches to appear. Each of these has the same structure as the stem from which it arises (*fig.* 907).

The roots are adventitious and are produced from the nodes of both rhizome and sub-aerial stem. In the former case they grow into elongated structures, but in the latter they remain rudimentary and never grow out from the tissue of the stem.

In a few species the flowering shoot is different from the form described above; it either does not produce branches, or very few occur upon it, or they are not developed till the spores are shed. In one or two cases the sub-aerial shoot, whether sterile or fertile, remains almost or quite unbranched.

The green colour of the plant is due to the stem, the leaves being brown and scaly.

The sporophylls are gathered together at the apex of the fertile shoot, and they form a conical mass which may properly be considered as a flower. Its structure is a thin cylindrical axis on which a number of peltate leaves are arranged close together in a succession of whorls. Each leaf or sporophyll consists of a thick flattened head, to the centre of which a stalk is attached at right angles. On that side of the peltate head or blade which is turned towards the axis, there are a number of sessile sporangia. Each leaf may bear from five to ten, all of which contain numerous spores (*fig.* 906).

Just below the flower there is a ring of curiously modified leaves, forming what is known as the *annulus*.

Equisetum grows by means of an apical cell, as do the Ferns. Such a cell is to be found at the apex of stem, branch, and root (*fig.* 908).

A transverse section of the rhizome, taken a little way from the growing point, shows its exterior divided into ridges and furrows. Opposite to each furrow there is, a little way from the surface, a large lysigenous intercellular cavity. These together are known as *vallecular* cavities. They are interrupted at the nodes, where a sheet of parenchymatous tissue stretches across them.

Fig. 906.

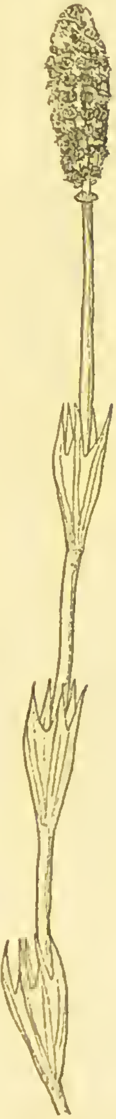


Fig. 907.

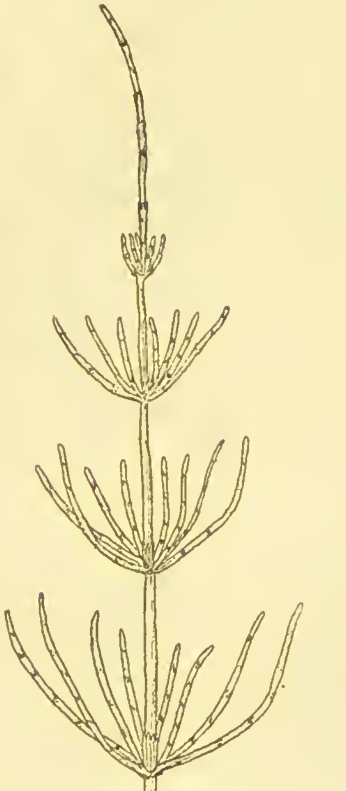


Fig. 906. Fertile stem of *Equisetum* bearing a flower or cluster of sporophylls.—*Fig.* 907. Sterile shoot of *Equisetum*

Fig. 908.

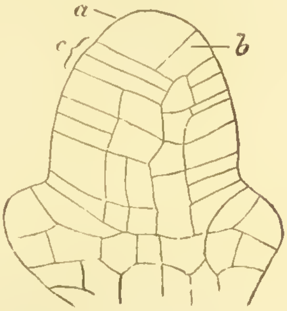


Fig. 908. Growing point of shoot of *Equisetum arvense.* × 250. *a.* Apical cell. *b, c.* Successive segments cut off from it.

A little internal to these cavities are the several steles, the plant being schizostelic. These are arranged differently in different species, and we may distinguish three varieties. In *E. litorale* (*fig* 909, A) the steles are all separate, each is clothed with pericycle and endodermis, and they are arranged in a ring round the stem. In *E. silvaticum* (*fig.* 909, B) the separate steles fuse together laterally, forming a gamodesmic mass. The result is that the endodermis is then absent from the sides of the steles, and the portions remaining behind and in front of each stele fuse together, forming two continuous bands, one surrounding the whole collection and the other forming an internal lining to it (*fig.* 909, B). In *E. palustre* the inner endodermal layer is not well marked, the cells not thickening in the same way as those of the outer. This rhizome appears to be monostelic, though it is not really so.

FIG. 909.

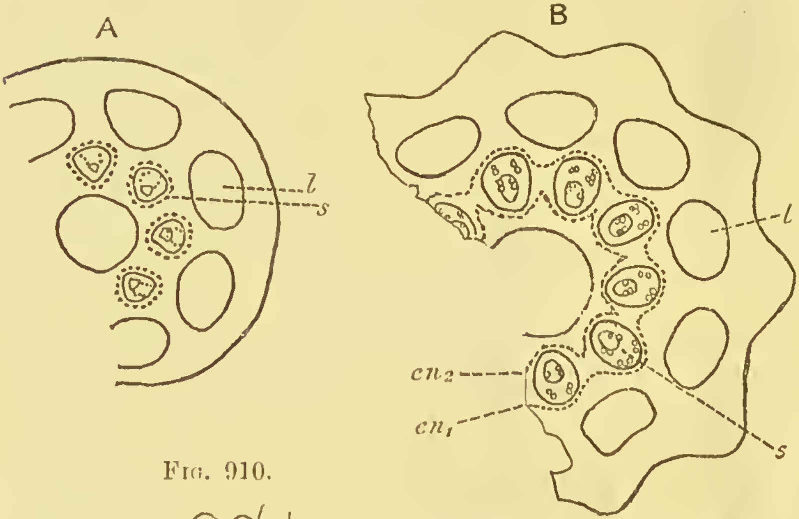


FIG. 910.

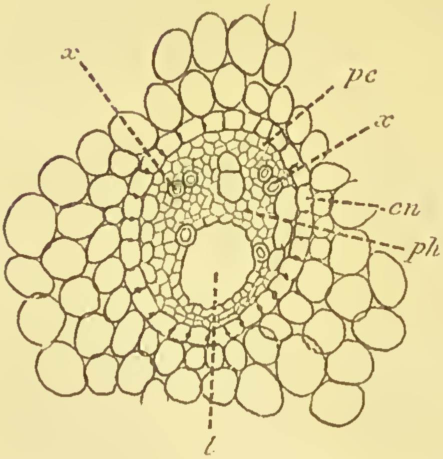


Fig. 909. Diagram of stem in two species of *Equisetum*. A. *E. litorale*. *s*. The separate bundles or schizosteles, each with its endodermis. B. *E. silvaticum*. The schizosteles, *s*, have their endodermis fused laterally. In both figures *l* = cortical lacunæ. After Pfitzer. —*Fig.* 910. Section of vascular bundle of *Equisetum limosum*. *en*. Endodermis. *pc*. Pericycle. *x*. Xylem. *ph*. Phloëm. *l*. Carinal lacuna. After Dippel.

The centre of the rhizome is in most cases filled with parenchymatous tissue, forming a kind of pith. In some it is a large air-cavity.

There is a considerable development of sclerenchyma just under the epidermis, forming a very strong hypoderma.

Each stele consists of a single closed collateral bundle, the wood of which is much reduced. Generally the latter consists of the protoxylem and two groups of tracheïds (*fig.* 910, *x*). In the region of the wood the stele contains a conspicuous air-space, the *carinal* cavity, into which the elements of the wood often protrude (*fig.* 910, *l*).

The sub-aerial shoots differ from the rhizome by always having a very large central cavity, extending as before through the several internodes and being interrupted at the nodes. The arrangement of the steles is the same as in the underground stem. The cortex shows similar lacunæ, but it contains a number of bands of tissue with chloroplastids, which vary in their position and arrangement. The sclerenchyma is developed in strands opposite to the ridges. The epidermis contains in its cell-walls copious deposits of silica.

The vascular bundles pursue a straight course down the internodes. At every node, each bundle bifurcates and the two halves diverge; each half unites with half of the next laterally placed bundle, the conjoint bundle passing then down the next internode in the same manner. At each point of junction of two half-bundles a strand from a leaf joins the united portions (*fig.* 911), so that the bundles are *common.*

Fig. 911.

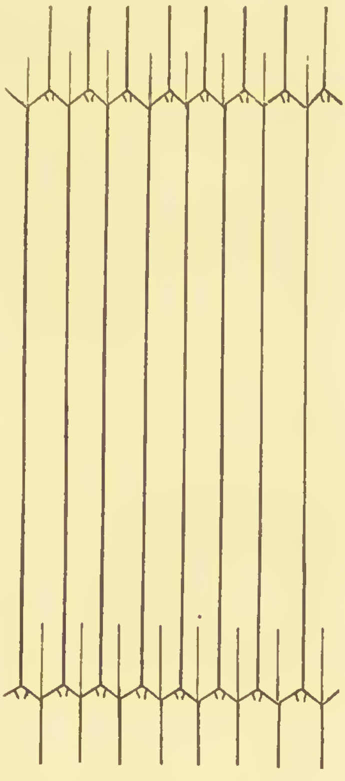


Fig. 911. Diagram of the course of the fibro-vascular bundles of *Equisetum* through two nodes and one internode.

The leaf is very rudimentary, having only a single small vascular strand passing up the centre. It contains no chloroplastids.

The vascular cylinder of the root is monostelic; the stele contains three wood and three bast bundles and is invested by a double-layered endodermis, from the innermost layer of which the lateral branches spring. There is no pericycle.

The sporangia are ovoid bodies, arranged with their long axes pointing towards the stem. Each is derived from several epidermal cells, the Equisetinæ being *eusporangiate.* The wall of the sporangium is one layer of cells deep, and these have peculiar thickenings similar to those of the anthers of the higher flowering plants.

The spores are all alike, the Equisetinæ being isosporous. A perinium, or epispore, is developed, resembling somewhat that of the spores of *Marsilea.* When the spores are mature, this coating splits up into four bands which coil round the spore, being attached to one point of its surface. These are known as *elaters*, and they aid in the dissemination of the spores by virtue of their hygroscopic qualities.

When the spore germinates it produces a gametophyte or prothallium very much like that of the Ferns, but somewhat more irregular in contour.

The prothallia are generally diœcious, producing antheridia or archegonia, but not both. The antheridia and archegonia closely resemble in structure and development the corresponding organs in the Fern.

The embryo produced from the zygote has two cotyledons, contrasting with that of the Ferns, which has only one. The octants, with this exception, behave much as in the latter group.

The Equisetinæ were represented in Carboniferous times by a very prominent group of plants now known under the name of *Calamites.* Some of these were heterosporous. Though much like the existing forms, they showed a certain variety in the mode of arrangement of the sporophylls. They differed very greatly in anatomical structure on account of the bundles being *open* instead of *closed.* The cambium gave rise to considerable amounts of secondary wood and bast, so that the Calamites increased in thickness as do now the Dicotyledonous flowering plants.

CLASS VIII.—LYCOPODINÆ.

Like the Filicinæ, this class embraces both isosporous and heterosporous forms, and is divided accordingly. The plant is the sporophyte, and all the plants of the class are eusporangiate. Though of a somewhat higher type than the Ferns and Horsetails with regard to their processes of reproduction, their vegetative body is usually not so conspicuous, though in this respect there is a great deal of variety. The development of the embryo from the zygote, so far as it has been followed in the group, is much more like the process found in the Spermaphyta. The *foot*, so prominent in the embryo of the Ferns, is replaced by a cell or filament of cells known as a *suspensor*, and a special absorbing structure is developed from the epibasal portion of the embryo, which is often erroneously spoken of as a foot. It functions in the same way as a true foot, but is developed from an altogether different part of the embryo. We have, indeed, in the action of the foot in the Ferns and of this new organ in the Lycopodinæ an instance of the same physiological function being discharged by morphologically different members.

SECTION 1.—ISOSPOROUS LYCOPODINÆ.

Included in this section are two Natural Orders, Lycopodiaceæ and Psilotaceæ, each of which comprises two genera, *Lycopodium* and *Phylloglossum*, *Psilotum* and *Tmesipteris*.

Lycopodium is much the largest genus, comprising many species of very varying external appearance. Generally there is a very much-branched wiry stem, sometimes growing underground, sometimes creeping on the surface, sometimes erect. It is closely covered with variously arranged small, pointed leaves, which are very numerous. The stem sometimes branches dichotomously, sometimes monopodially.

Besides the foliage leaves the plant bears sporophylls, which are often very different in appearance from the former, and are collected into flowers at the end of the branches. The flowers are cones, consisting of spirally arranged leaves bearing the sporangia in their axils or on the upper surface of the leaf-stalk (*fig.* 914). In some species the collection of the sporophylls into cones is not so obvious, and then the sporophylls closely resemble the foliage leaves. The roots are all adventitious, and in many cases arise from superficial cells of the stem.

Phylloglossum has a tuberous stem, from the apex of which about six leaves spring. These are longer than in *Lycopodium* and form a sort of rosette, from the centre of which arises a peduncle bearing the single flower. This is a small simple cone, the upper leaves of which do not bear sporangia. The whole plant is only a few inches in height.

Psilotum in appearance resembles a very small bush. It has a much-branched subterranean rhizome, from which arise numerous sub-aerial stems. There are no roots, the subterranean shoots discharging their functions. The foliage leaves are considerably reduced, being very small and sparsely distributed. The sporophylls are bilobed and stalked.

Fig. 912.

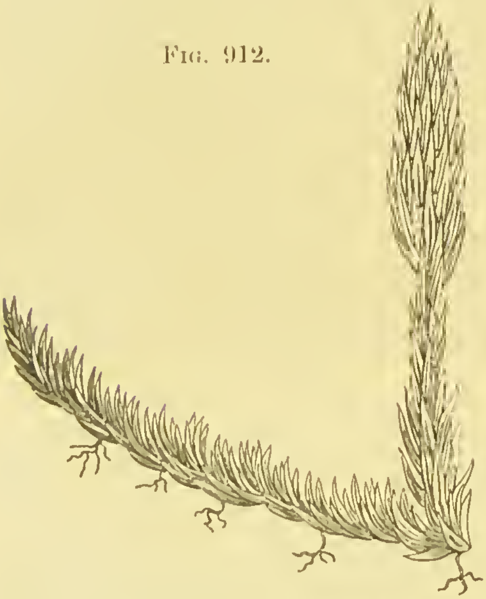


Fig. 912. *Lycopodium inundatum*, Marsh Club-moss. The stem is creeping, and bears numerous small sessile imbricate leaves.

Tmesipteris grows upon the trunks of tree ferns, the stems being pendulous and clustered. Each stem is slender and crowded with linear sessile foliage leaves, among which occur sporophylls much like the former, but stalked and bearing sporangia.

The anatomy of the stem in this group presents some very characteristic features. The apical cell of the lower Cryptogams becomes replaced by a small-celled meristem resembling that of the apical growing point of the Phanerogams. In a few cases, but only exceptionally, an apical cell occurs. The stem is monostelic, and its vascular bundles are arranged radially as in most roots (*fig.* 913). There are generally numerous wood and bast bundles, the protoxylem and protophloëm of which are placed alternately in a circle round the stele, abutting on the pseudo-pericycle. As the wood develops, the separate bundles become united together, fusing into masses of irregular pattern, between which lie masses of bast similarly formed by fusion of the primary bundles. In their downward course the fused masses of wood are found to separate again and rejoin in other ways, the anastomoses causing the transverse section of the stem to present different patterns at different levels. The endodermis is usually thick-walled, and surrounds a layer which occupies the place of a pericycle, but which is really cortical and not stelar in its origin. This layer usually gives rise to the adventitious roots.

The root is similar in structure to the stem, but it contains fewer bundles of wood and bast. Its apical meristem is composed of small cells.

Fig. 913.

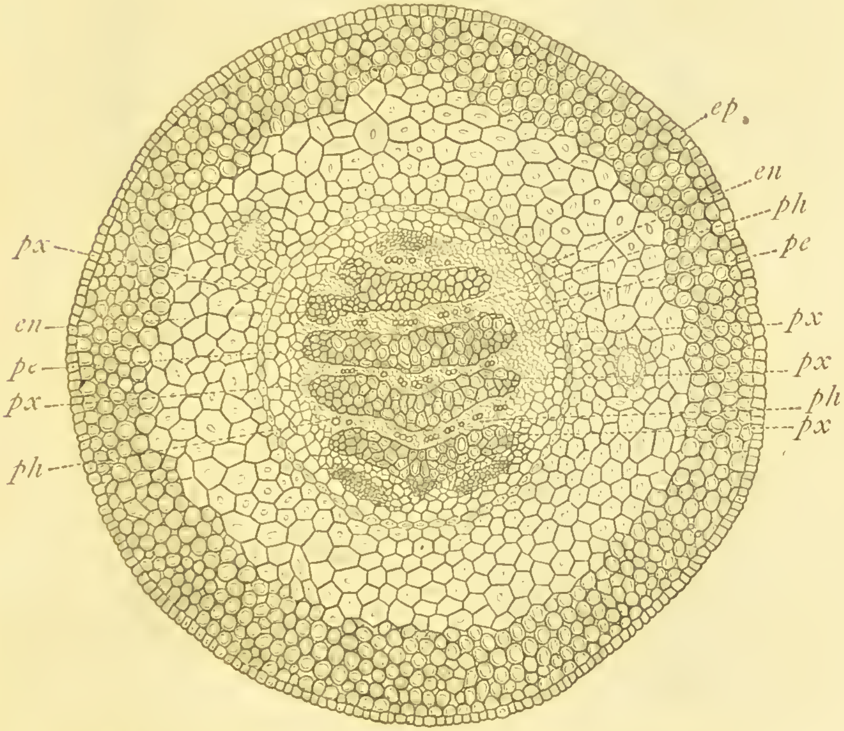


Fig. 913. Section of stem of *Lycopodium*. *ep.* Epidermis. *en.* Endodermis. *pe.* Pseudo-pericycle. *px.* Groups of protoxylem. *ph.* Phloëm. After Sachs.

The stem or tuber of *Phylloglossum* contains little vascular tissue. Bundles from the leaves and roots anastomose where they enter it, and from the network a single strand passes up to the peduncle of the cone.

Both *Psilotum* and *Tmesipteris* agree with *Lycopodium* in being monostelic, with bundles arranged radially. The cortex of the stem of *Lycopodium* can be divided into two areas, composed of thick-walled woody cells with small intercellular spaces. The cells of the inner area have the thickest walls. The cortex is crossed by bundles passing out from the stele to the leaves.

The sporangia in *Lycopodium* and *Phylloglossum* are simple and stalked. They arise on the leaves near their insertion (*fig.* 914). They arise from several cells instead of from a single one as in the Ferns. They show no special peculiarity in their development. The spores are all of one kind.

Fig. 914.

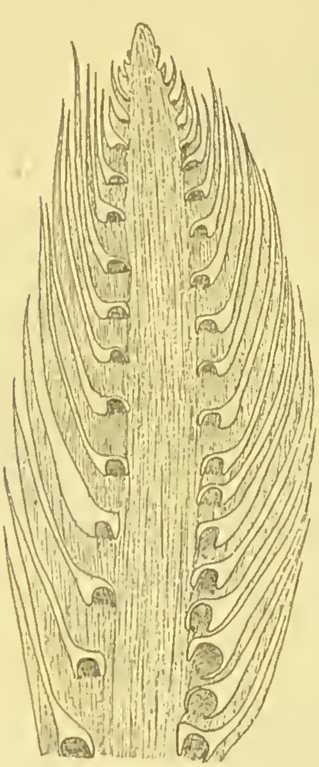


Fig. 915.

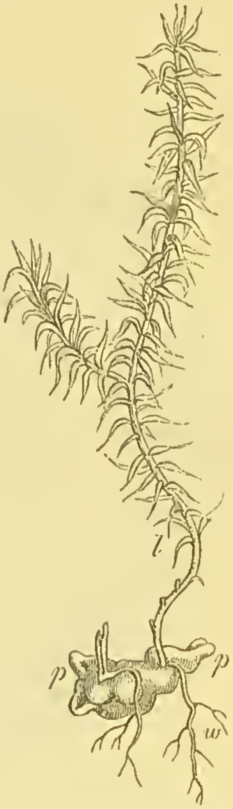


Fig. 914. Longitudinal section of cone of *Lycopodium*, showing the sporangia in the axils of the sporophylls.——*Fig.* 915. *Lycopodium annotinum*. *p*. Prothallium. *l*. The young plant. *w*. Its root. After Funkhauser.

In Psilotum and Tmesipteris the sporangia are bilocular or trilocular, being *synangia*, as in the Marattias. They are stalked bodies, borne upon the upper surface of the bilobed sporophyll at the junction of its two lobes.

The gametophyte or prothallium (*fig.* 915, *p*) is only known in the genus *Lycopodium*, and shows considerable variety of form. In some species it is a small tuberous body, with a colourless base from which root-hairs spring, and an apex which is divided into several green lobes; in others it is altogether tuberous. In other species again it is larger and is a cylindrical branched body bearing gametophores. It bears both antheridia and archegonia, which resemble the corresponding organs in the eusporangiate Ferns. The antherozoids do not exhaust the protoplasm of the mother cells in which they are developed, but a small portion of it remains attached to them on their liberation as in the Ferns. They are biciliate.

The development of the sporophyte from the zygote is only known in *L. Phlegmaria*. The first division gives, as before, epibasal and hypobasal segments. The hypobasal cell does not as a rule divide, but elongates slightly to form the *suspensor*. The epibasal cell gives rise to the embryo, which consists of a primary stem, bearing a single cotyledon. The part of the axis below the cotyledon becomes the pseudo-foot already spoken of. It is really a *hypocotyl*. There is no primary or true root, but an adventitious one speedily arises from below the cotyledon.

In two other species (*L. cernuum* and *L. inundatum*) the later stages in the development have been followed, but the early ones are unknown. In them the appearance of the primary stem is preceded by the development of a tuberous body which bears the cotyledon and subsequently the stem at its apex. From its base adventitious roots arise exogenously.

Besides these modes of reproduction the vegetative method is not uncommon. Some species of *Lycopodium* multiply by gemmæ, others by tuberous outgrowths from the roots, others by the detachment of branches. *Phylloglossum* produces annually a single branch, which develops into the tuber of the succeeding year. *Psilotum* sometimes bears gemmæ on its rhizomes.

SECTION 2.—HETEROSPOROUS LYCOPODINÆ.

In this section we have two genera grouped together, about whose close affinity there is some doubt. These are *Selaginella* and *Isoëtes*. Of the relationship of the former to the isosporous Lycopodinæ there can be no doubt, but some authorities lean to the view that the affinities of *Isoëtes* are rather to the Ferns than to the present group. This view is based upon its general habit, the large leaves and the small stem being much more like the

Ferns than the Lycopods; its embryogeny, the hypobasal cell not giving rise to a suspensor; the isolated position of its sporangia, and the form of its antherozoids. On the other hand, it shows relationship to the Lycopods in the occurrence of the sporangia on the upper surface of the leaf near the base; in the peculiar features of the gametophyte arising from the megaspore, which approaches the condition obtaining in the Gymnosperms even more closely than that of *Selaginella*; in the occurrence of a peculiar outgrowth of the leaf close to the sporangium, which is shared only by *Selaginella*; and in the structure of its apical meristem. The adventitious nature of the first root also supports this view of its position.

FIG. 916.

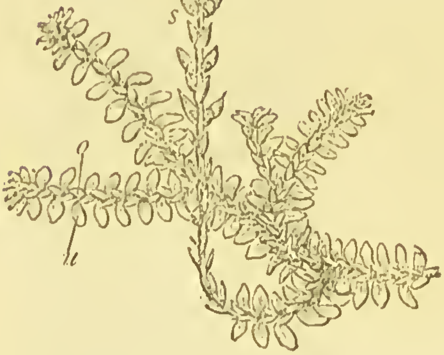


Fig. 916. *Selaginella helvetica.* *s.* Stem. *o.* Small leaves of upper surface. *u.* Larger leaves of lateral flanks.

The heterosporous Lycopodinæ have sometimes been called the *Ligulatæ*, from the occurrence of the particular outgrowth referred to, which is known as the *ligule*. *Selaginella* is the best known representative, and in many respects is the highest type represented in the group. Its form shows more variety than that of any other genus; the stem is slender, herbaceous, and sometimes erect, sometimes creeping; almost always showing a bilateral symmetry, which is very evident when it is much branched; the branches spread out in a flattened manner, and show an evident difference between the upper and under sides. The branching is apparently dichotomous and the stem a sympodium. Recent investigations tend to the view that the dichotomy is only apparent, and that it is really lateral.

The stem bears numerous small leaves of very simple structure. They are arranged in pairs, which are of unequal size, one leaf being much smaller than the other. The successive pairs decussate with each other, and in many cases, by some distortion in growth, the small leaves come to lie on the upper surface of the stem, while the larger ones are on the lateral flanks (*fig.* 916). Each leaf bears the peculiar ligule spoken of above.

The roots are adventitious as in other cases, even the primary root proceeding from the epibasal half of the zygote. This primary root soon perishes; the adventitious roots which succeed it spring from the lower surface of the stem, or from peculiar naked branches termed *rhizophores*, which grow down into the soil and develop roots from their apices.

The sporophylls are usually aggregated at the ends of certain of the branches; they form their flowers much as in *Lycopodium*, but there is not quite so sharp a distinction between the flowers and the foliage leaves as in the latter case. The sporangia, which are of two kinds, spring from the axils of the sporophylls, or in some cases from the surface of the stem just above the insertion of the latter.

The megasporangia usually contain four megaspores; the number of microspores is generally large.

In the details of its anatomy *Selaginella* presents some very characteristic appearances. The apical meristem is sometimes small-celled and stratified, but in some species there is a definite apical cell. In others there is a group of two or three large cells which behave like apical cells. The stem as seen in section (*fig.* 917) is composed of parenchymatous or prosenchymatous cells, embedded in which are one to three steles, the polystelic condition being the most usual. There is no sclerenchyma, and but few intercellular spaces; sometimes, indeed, the latter are absent altogether. Each stele is enclosed in a large air-chamber, and this chamber is crossed by delicate rows of cells or trabeculæ, which attach the stele to the walls. The steles are gamodesmic, and consist of a variable number of bundles which have their protoxylem groups external, abutting on the pericycle. A frequent number of bundles in the stele is two of xylem and two of phloëm; in such case the structure much resembles the stele of the Fern stem, the protoxylem being on the outside as in the former case. The structure is really of the same kind as in *Lycopodium*, the bundles being originally disposed radially. Not being so numerous as in the latter case, the subsequent fusions do not lead to so complicated a woody mass.

The leaves contain a single bundle, which in like manner is slung in an air-chamber. The base of the leaf is sometimes dilated into a kind of pulvinus, which is chiefly occupied by the air-cavity. The intercellular-space system being so much reduced, the stomata of the leaf open into these air-chambers.

The tissue of the root is more compact, there are no air-chambers, and usually a single central stele. The structure of the rhizophore resembles that of the root.

The sporangia are developed much as in *Lycopodium*; the megasporangia differ from the microsporangia in the number of divisions that take place in the cells of the archesporium. In the latter case many mother cells are produced, each giving rise to four tetrahedral microspores; in the former case not so many are formed, and only one of them as a rule divides to form spores. Hence the mature megasporangium contains four megaspores.

FIG. 917.

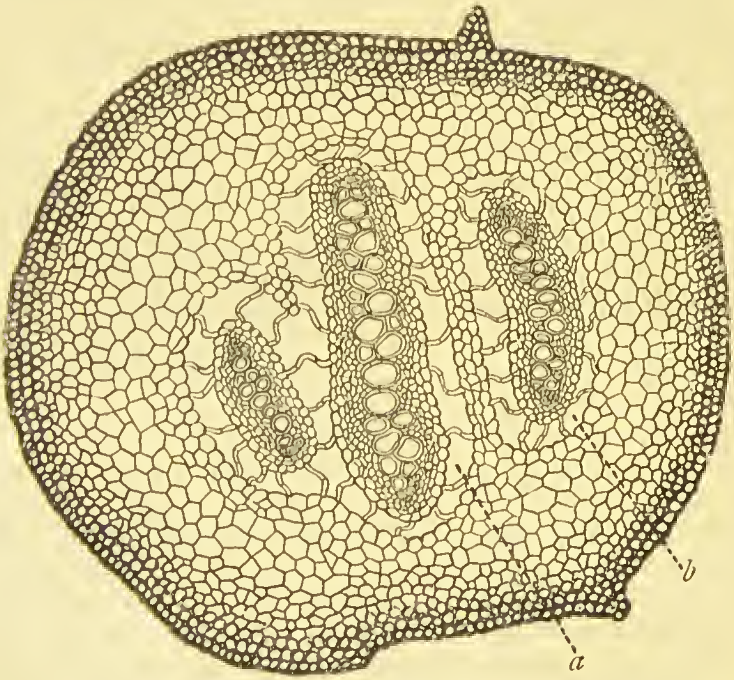


Fig. 917. Section of stem of *Selaginella* showing three steles. *a*, *b*. Air-chambers.

The male gametophyte arises from the microspore, and is very similar to that of *Marsilea*. The spore divides into two cells, a small vegetative one at the apex, and a large basal one which by repeated divisions produces a single antheridium, having a wall enclosing the mother cells of the antherozoids. The microspore does not rupture until the antherozoids are developed.

The germination of the megaspore gives rise to a prothallium which is very largely endosporous. The spore contains a small amount of protoplasm surrounding a large central vacuole. By free cell-formation a small primary prothallium is formed at the apex of the spore, which is soon separated from the remainder of the spore-cavity by thickening of the cell-walls of its lower layer, forming a *diaphragm* not unlike that of *Salvinia*. The protoplasm of the lower part of the spore increases till the cavity is filled with it. By free cell-formation it develops a tissue much like that of the primary prothallium but with larger cells. This has been called the *endosperm*. The upper portion of the prothallium is after its formation exposed to light and air by the rupture of the megaspore at its apex; it then becomes green from the development of chloroplastids. Generally it bears only one archegonium, never more than a limited number. Frequently the number produced depends upon whether the first becomes fertilised. They have the same structure as those of the eusporangiate Ferns.

Fig. 918.

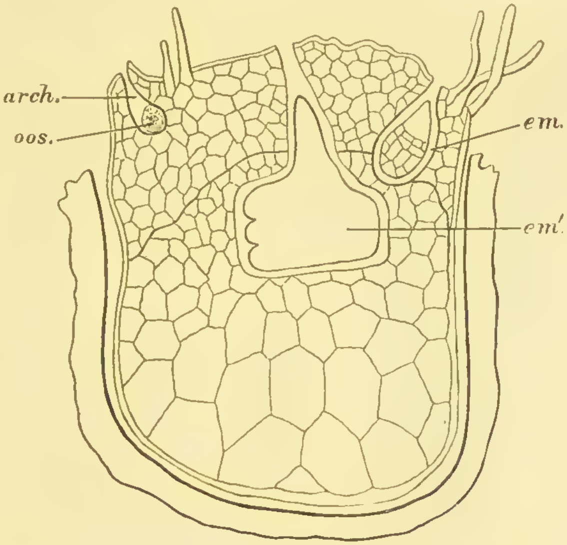


Fig. 918. Germination of macrospore of *Selaginella*. After Pfeffer. *arch.* Archegonium. *em*, *em'*. Young embryos.

The archegonia have the usual structure found in the group. Fertilisation of its oosphere is also normal.

When the zygote is formed and its germination begins, the process is similar to that of *Lycopodium*. The hypobasal segment becomes the suspensor, which by its elongation forces the young embryo down into the tissue filling the cavity of the spore, the so-called endosperm. The epibasal cell forms four octants, and from these arise the growing points of the stem and of two cotyledons. As the growth of the embryo proceeds, a pseudo-foot is developed from the hypocotyledonary region, and the direction of growth of the axis becomes changed, so that the stem gradually curves upwards to emerge from the spore at the crack at its apical region, through which the prothallium is partially protruding. The foot remains embedded in the tissue of the endosperm and absorbs its contents. The first root is developed from cells in the interior of the hypocotyl between the foot and the suspensor.

Fig. 919.

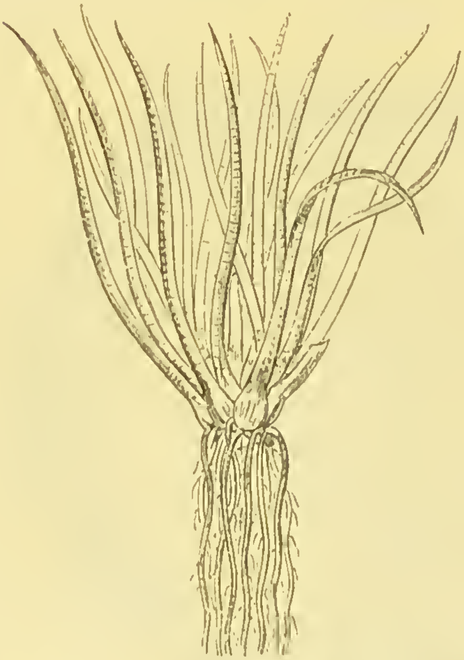


Fig. 919. *Isoëtes lacustris*, Lake Quill-wort. The stem is small and corm-like, and bears its leaves, which are linear-cylindrical, in tufts.

The other member of this section, *Isoëtes*, differs from *Selaginella* very markedly in its habit. It has a short tuberous stem somewhat lobed externally, from which spring numerous leaves in a cluster. The leaves are long and narrow, some of the cluster being fertile and some sterile. The fertile leaves bear large sporangia in a kind of pit upon the upper surface at their base. The microsporophylls are developed later than the megasporophylls. Each leaf bears a ligule as in *Selaginella*. Numerous roots spring from the under side or base of the tuberous stem, and these branch dichotomously.

The stem is monostelic, and grows by a meristem, which consists of several large so-called apical cells. The stele is composed of a number of fused collateral bundles, which are common and run out into the leaves. Outside the bast of the bundles is a merismatic ring, which forms vascular tissue internally, and externally adds to the cortex of the stem. *Isoëtes* thus increases in thickness, but somewhat irregularly, the distribution of the new cortical tissue being interrupted at places in the ring, so causing the furrows noticeable on its exterior.

The leaves have a single bundle, which is of a somewhat reduced type. It runs down the middle of the blade into the stem, and joins the ring of the stele. Four large air-spaces run down the whole length of the leaf in the parenchymatous tissue (*fig.* 920).

FIG. 920.

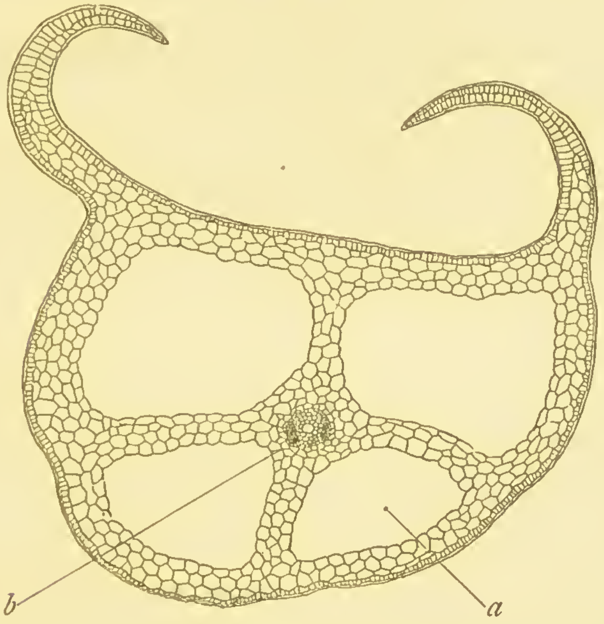


Fig. 920. Transverse section of leaf of *Isoëtes lacustris*. *a*. Air-chamber. *b*. Fibro-vascular bundle.

The root differs from the stem in having a small-celled stratified apical meristem. Its stele contains only one or two bundles of xylem and phloëm.

The sporangia are much more bulky than in any other of the Lycopodinæ. They arise in a depression or pit on the upper surface of the leaf just above its base, a little below the insertion of the ligule. *Isoëtes* is eusporangiate, the sporangium arising from a group of cells. In the microsporangium the archesporial tissue, which becomes bulky, has its cells arranged in radial rows, springing from a sort of pad or cushion at its base. There takes place in the archesporium then a process of sterilisation of certain of these cells, recalling the formation of the elaters in the Liverworts. The sterile cells extend as trabeculæ or strands across the interior of the sporangium, so that in transverse section it appears to be septate. In the microsporangium other cells also sterile, though derived from the archesporium, form a tapetum, which surrounds the mass of microspores. In the megasporangium there is a similar formation of trabeculæ, but the arrangement of the rest of the archesporial tissue is different. There are fewer cells, which are consequently larger, and a tapetum is formed round each mother cell.

The sterilisation of the tissue forming the trabeculæ, like that of the tapetum, is probably due to the need of distributing nourishment for the spores throughout the large sporogenous mass.

The gametophytes of *Isoëtes* closely resemble those of *Selaginella*. The prothallium derived from the megaspore is even more completely endosporous, the development being advanced to the stage of maturity of the archegonia before the spore splits. The prothallium consequently never becomes green. The antheridia and archegonia resemble in all points those of *Selaginella*.

The development of the young sporophyte from the zygote recalls that of the Ferns. Both epibasal and hypobasal segments divide to form the octants; the hypobasal ones all combine to form the foot, but the first root is developed from the epibasal segments, which also give rise to the stem and the single cotyledon. The root is consequently adventitious, as in *Selaginella*.

Like the Equisetinæ, the Lycopodinæ were represented in Carboniferous times by very massive forms which showed great cambial activity in the development of their trunks and roots. Of these *Lepidodendron* is the best known example.

CHAPTER VI.

GROUP IV.

SPERMAPHYTA OR PHANEROGAMIA.

THIS group of plants, so long considered as one standing apart from and above all others, or corresponding in classificatory value to the whole of the Cryptogams, is now held to be properly only upon an equal footing with the other groups already discussed. The gradual increase of complexity of structure of the sporophyte, associated with the progressive degradation of the gametophyte, reaches its maximum in this group, which appears as the fourth member of the series into which the Vegetable Kingdom is now divided.

The heterosporous character of the sporophyte, which we have seen to appear irregularly in the Pteridophyta, is here constant. The microspores are developed in much the same way and in about the same numbers as in the latter group; the megaspores show a considerable degradation, and the megasporangia never become free from the parent plant until some time after their gametophytes are mature, not indeed until the young sporophyte or embryo produced by each of the latter has attained a considerable degree of development. The result is that a peculiar structure known as the *seed* makes its appearance for the first time in this group of plants. As its development shows some variability, it will be well, for the present, to defer its consideration. On account of its constant occurrence, the group is sometimes called the *Spermaphyta*.

The general morphology and anatomy of the group have formed the subject of the greater part of the first two sections of this manual, and need not, therefore, be treated of at length in the present chapter.

The chief remaining points calling for attention in connection with the Phanerogams are the structure of the sporophylls; the development of their sporangia, and spores; the gametophyte generation; and the embryogeny of the sporophyte.

The arrangement of the sporophylls has been discussed in connection with the morphology of the reproductive organs (Vol. I. Chapter II.), where their collection with other leaves into special branches, called *flowers*, has been fully treated of.

This development of a special branch system in connection with the occurrence of spores has been seen in the previous groups, especially in the Pteridophyta, not to be peculiar to the Phanerogams, but to be clearly indicated in the Equisetinæ and the Lycopodinæ. What is, however, exceptional in the lower forms becomes in the Phanerogams a constant and characteristic feature of their life.

It has been already pointed out that in the Phanerogams the sporangia, though usually borne upon leaves, are sometimes axial in their origin (*fig.* 921). This is seen in the case of both microsporangia and megasporangia. When borne upon leaves, these are known as microsporophylls and megasporophylls respectively. The microsporophylls are also called *stamens*, or staminal leaves; while the megasporophylls are termed *carpels*, or in some cases carpellary leaves or scales. The microsporangia, often called *pollen sacs*, are situated at different places upon the stamen or staminal leaf. In the Gymnosperms they are upon the under side; in the Angiosperms upon both surfaces. The megasporangia, or *ovules*, arise from a special parenchymatous cushion already described as the *placenta*, which in the Gymnosperms is usually on the ventral surface of the sporophyll or carpellary scale, but in the Angiosperms is almost always a development of the margin of the carpel. The carpel, or frequently the collection of carpels in a flower, forms by various cohesions at their bases in the latter case a closed chamber or *ovary* in which the megasporangia are concealed.

FIG. 921.

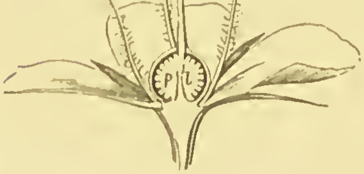


Fig. 921. Vertical section of flower of Pimpernel, showing axial megasporangia.

Based on this latter point we have the classification of the Phanerogams into two large divisions, *Gymnospermæ*, in which the ovules are exposed, and *Angiospermæ*, in which they are enclosed in an ovary. Each of these large groups presents important peculiarities, the Gymnosperms approaching the

Pteridophyta much more nearly than the other forms, especially in the structure of the gametophyte and the differentiation of the sexual organs.

THE MICROSPOROPHYLLS, AND THEIR SPORANGIA.—The microsporophyll varies a good deal in its form; in the Gymnosperms it may be a flattened leaf with sporangia on its under surface; it may be a peltate scale, something like that of the flower of Equisetum, or it may be a short branched axis bearing a variable number of anther lobes. In the Angiosperms it is the structure already described as a *stamen*, consisting of a filament, carrying at its apex a swollen head or anther.

The Microsporangia are distributed in various ways upon the sporophyll; in most cases in groups which are to be considered as sori, corresponding to the sori in the Ferns and their allies. In the Gymnosperms the flattened staminal leaf of the Conifers has a sorus of two sporangia on its back; the sporophylls of the Cycads bear a number of groups of sporangia, each group representing a sorus. The anther of the Angiosperms contains a sorus of four sporangia, the pollen sacs. The indusium or membrane covering the sorus in the Ferns is represented doubtfully in the Cupressineæ, where the sporangia when young are covered by an outgrowth of the under surface of the sporophyll.

Whether the sporangia arise upon a sporophyll or upon the axis, their mode of development is the same. They are eusporangiate, that is, they originate in a group of several cells. In the young anther, at four places, corresponding to the anther lobes, a row of hypodermal cells is seen to be somewhat different from the rest in their mode of dividing. In a transverse section of the anther they appear as four cells, as the row runs longitudinally. The hypodermal cell so seen in transverse section cuts off a cell from itself on its exterior face; this division is followed by another one parallel to the first, so that the original cell or archesporium is replaced by a row of three, of which the innermost has come to lie more deeply in the tissue. The outer two take no part in the development of the spores, which arise from the inner one. The one lying next to this is the first-formed part of a nutritive layer which is made to extend round the sporogenous cell by divisions taking place in the tissue next it. This layer is known as the *tapetum* and has only a transitory existence. The outermost of the three cells becomes similarly extended, and the walls of those cells which are towards the exterior become thickened spirally, constituting the external wall of the pollen sac. Both these layers become composed of many cells, owing to radial or anticlinal divisions of those first formed. The innermost cell divides into a variable number of cells, which are the mother cells of the microspores or pollen grains. Each mother cell gives rise to four special mother cells; in the Monocotyledons by ordinary cell-division twice repeated, the plane of the second division being at right angles to that of the first: in the Dicotyledons the four special mother cells are arranged at the four angles of a tetrahedron, as described in the case of the Ferns. Each special mother cell gives rise to a pollen grain, or microspore, by a process of rejuvenescence. The tapetum, and frequently the walls of the original mother cells, become disorganised, forming a sort of mucilaginous fluid in which the spores float. As they mature their walls are thickened from within and usually form two coats, the intine and the exine. The exine is often curiously marked with spines or ridges, due to the deposition of matter upon it from the disorganised tapetal cells. Eventually the spores lie free in the cavity of the sporangium.

Fig. 922.

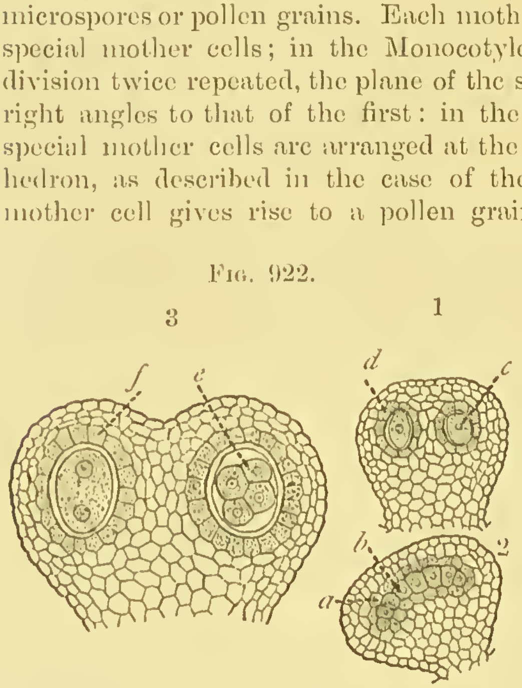


Fig. 922. Development of pollen in the stamen of *Lavatera*. 1, 2. Young stages. 1. Transverse, 2. Longitudinal, section of anther. *a*, *d*. Tapetum. *b*, *c*. Sporogenous cells. 3. Later stage. *f*. Tapetum. *e*. Four special mother cells of the pollen. After Dodel-Port.

Dehiscence is secured by the hygroscopic character of the wall of spirally thickened cells described above, which under different atmospheric conditions ruptures either by longitudinal or transverse slits, or occasionally by a pore at or near the apex.

The microspore so formed is a rounded, or oval, or rarely an elongated body, containing protoplasm and nucleus, and a quantity of reserve food material consisting of proteïds, starch, oil, &c. It has usually two coats, of which the outer is hard and thickened, the inner thin and delicate. In some of the Gymnosperms the outer coat is expanded at two places at the base of the spore to form two bladder-like bodies which are filled with air.

The two coats are usually distinct from each other, but in some pollen grains they are adherent, except at special spots, at which the exine will rupture when the spore germinates. In some cases there is no exine, particularly in some aquatic plants.

The microspores do not always become free from each other; in the *Mimosæ* they are bound together by the special-mother-cell walls into groups of four or more; in the Orchids and *Asclepias* the whole mass is usually coherent, forming the *pollinium.*

The Megasporophylls and the Megasporangia. — The appearance of the megasporophylls has already been described. In the Angiosperms they are the carpels, and may be either free or coherent together. In the Coniferæ of the Gymnosperms they are flattened, scale-like leaves, each of which bears two sporangia on an outgrowth of its upper face. In some of the Cycads they are small pinnate leaves, the lower pinnæ only bearing the sporangia. In others they are peltate scales with the latter on their under side, much resembling the microsporophylls.

Fig. 923.

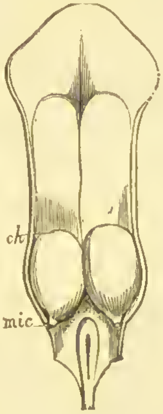


Fig. 924.

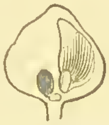


Fig. 923. A mature ovuliferous scale of the Scotch Fir (*Pinus sylvestris*), with two winged naked seeds at its base. *mic.* Micropyle. *ch.* Chalaza.— *Fig.* 924. A scale of the Larch, bearing one naked winged seed; the other seed has been removed.

The development of the megasporangium or ovule takes place by the division of certain hypodermal cells of the placenta, whether the latter be upon a sporophyll or upon the axis. These cells divide repeatedly periclinally till the young sporangium appears as a little protrusion of tissue, whose cells are arranged in radial rows (*fig.* 925). In the most usual case the terminal cell of the central row becomes the archesporium. The growth of the mass of the sporangium, known as the nucellus, has already been described (Vol. I. p. 212) and its various shapes mentioned. From its base arise the integuments, usually two in number, which accompany it in its growth and finally surround it, except at the apex, where the micropyle is left.

While this development is proceeding changes take place in the interior. The original archesporium, which is a single cell, cuts off one or sometimes two cells at its apex, the innermost of which represents the tapetum. These tapetal cells in some cases divide repeatedly, especially in the Gymnosperms, so that the innermost cell often comes to lie deep in the tissue of the nucellus. This is frequently, in the same group, secured by additional multiplication of cells derived from the epidermis of the nucellus over the apex of the archesporium. The innermost cell produced by the archesporial divisions now enlarges to a considerable extent. It represents the mother cell of the spores of the microsporangium. Instead of dividing to form special mother cells as in the latter, it becomes itself

Fig. 925.

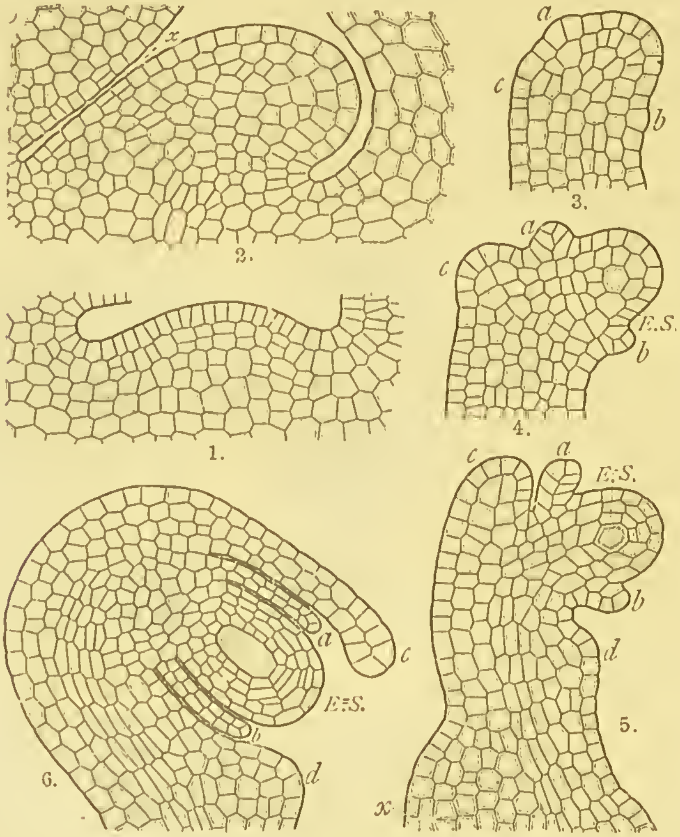


Fig. 925. Early development of an anatropous ovule. 1–6. Successive stages. *a*, *b*. Inner integument. *c*, *d*. Outer integument. *E.S.* Embryo sac. After Kny.

the single spore. It was formerly described as the *embryo sac*, as the embryo ultimately makes its appearance in it. During its growth, which is very considerable, it absorbs the cells around it, often to such an extent that it leaves nothing of the original nucellar tissue. It may even encroach upon the integuments. It then forms a large cell, clothed only by the integuments of the sporangium. If the absorption of the nucellus is not complete, the remainder of its cells form the tissue already alluded to as the perisperm.

The nucellus of the ovule is seen thus from its development to be the megasporangium of the Phanerogam, and to correspond to the megasporangium of *Selaginella*. It differs from the latter in that the mother cell of the spore becomes itself the spore, whereas in *Selaginella* the corresponding cell divides twice, forming four megaspores. It differs further in not secreting a thickened coat, its wall always remaining thin and delicate, except in the Cycadeæ, where it is double.

Though this is the usual course of development in the Phanerogams, there are many variations of the process known. More than one row of cells in the nucellus may give rise to archesporia, and consequently more than one embryo sac or megaspore may be produced. Eventually only the central one becomes mature, the others perishing early. In some cases, instead of a single-spore mother cell occurring, this divides into a number of sporogenous cells, of which again several may begin to develop into megaspores, though ultimately only one of them matures. In a few plants the original archesporium does not cut off any tapetal cells.

The features of the gametophyte generation and the embryogeny of the sporophyte differ considerably in the Gymnosperms and the Angiosperms, and will be best described in connection with those respective groups.

DIVISION A.—GYMNOSPERMÆ.

CLASS IX.—GYMNOSPERMÆ.

The plants included in this class are distinguished from those of the next by their megasporophylls never forming an ovary. In habit they are shrubs or trees, generally of considerable size. In our climate they are chiefly represented by the Coniferous trees, Firs, Larches, &c., which have a monopodially branched stem. They usually bear elongated branches, and in some families dwarf shoots arise upon them, which consist of small fascicles of two or more elongated green leaves springing from a short axis and surrounded at their bases by minute withered or brown scales. The number of leaves in each fascicle varies in different genera. In some cases the foliage leaves are borne exclusively on these dwarf shoots; in others they arise also on the elongated shoots. In others again they are confined to the latter, and dwarf shoots do not occur.

The stem in other members of the group is a short thick trunk, bearing large pinnate leaves; in *Welwitschia* it is very short and bears only two leaves, which are very long.

A few forms have a bushy habit, with wiry stems which bear no foliage leaves, but only a number of scales.

The sporangia are of two kinds, as already stated. The microsporophylls are usually collected into cones, and bear the sporangia on their lower surfaces. The megasporangia are axial in *Taxus* and in the *Gnetaceæ*; in the other cases they are borne on sporophylls. These, like the microsporophylls, are generally arranged in cones, but the sporangia are on the upper surface at the base of the sporophyll, sometimes upon a large placental scale. In *Cycas* the sporophyll is a pinnate leaf, the lower pinnæ of which are replaced by megasporangia. A cluster of these sporophylls is developed at the apex of the stem among the foliage leaves.

The development of the sporangia and of the spores has already been described.

A few features of the histology are remarkable. The stem is of the same type as that of the Dicotyledons, but is peculiar in that the wood formed by the cambium, except in the *Gnetaceæ*, always consists of fusiform tracheïds with bordered pits upon their radial walls. The sieve tubes, like those of the Pteridophyta, have no companion cells. There is a great development of secreting ducts in most cases, the secretion being either resin or mucilage.

THE GAMETOPHYTE.—As there are two kinds of spore, there are two forms of gametophyte, the male organs occurring on the one developed from the microspore, the female on that proceeding from the megaspore.

FIG. 926.

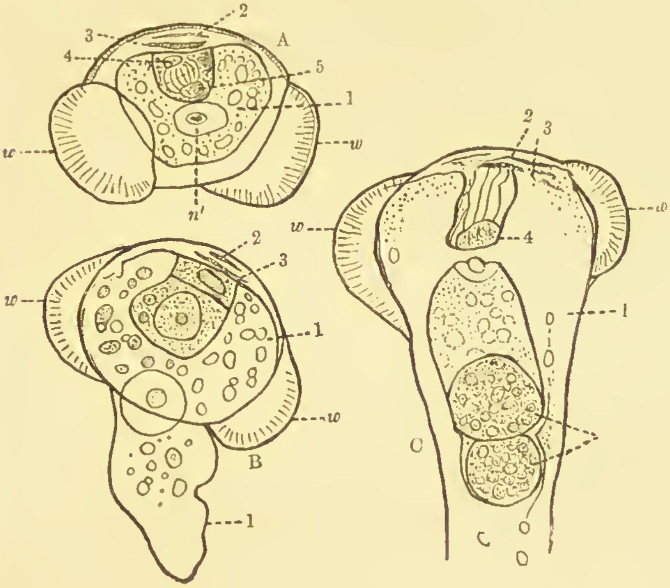


Fig. 926. A. Pollen grain of *Picea excelsa*, showing commencement of germination. *w*, *w*. The wings. 1. The large vegetative cell; its protoplasm is contracted; *n'*, its nucleus; 2, 3, the two collapsed cells; 4 and 5, the stalk cell and generative cell not yet completely divided from one another. B. A little older grain, showing germination a little further advanced and the pollen tube beginning to appear as an outgrowth of the large cell, 1. Lettering as before. C. More advanced stage, showing only upper part of the pollen tube. The generative cell, 5, has divided into two, each with a very large nucleus. ×240. After Strasburger.

The pollen grain generally begins to germinate before it is set free from the microsporangium. It divides into two cells one of which is much larger than the other. In some species more than one small cell is produced, the whole series of them being then looked upon as a rudimentary prothallium. The small cells which are formed first are soon absorbed, except the last one, which is known as the *antheridial* cell.

It soon divides into two, one of which remains small, while the other increases and projects for some distance into the cavity of the larger cell (*fig.* 926, B). The projecting cell is known as the *generative* cell, the smaller one being termed the *stalk cell.* After the pollen grain has been liberated from the sporangium the large cell grows out into a long filamentous body, known as the pollen tube; its wall is composed only of the intine of the spore, the exine rupturing to give it exit.

The generative cell and the nucleus of the vegetative cell both make their way down the pollen tube; the vegetative nucleus breaks up and disappears; the generative cell divides into two, which represent the mother cells of antherozoids of the Pteridophyta, while the stalk cell disintegrates and disappears. In *Ginkgo* and in a species of *Cycas* these cells give rise to ciliated antherozoids of peculiar shape. In all other cases the antherozoid is not differentiated. In some forms there is a still further division of the generative cells at the apex of the pollen tube. The ultimate cells, whether the divisions be one or many, are naked cells and constitute the male gametes. They are eventually extruded from the pollen tube.

The prothallium which is produced from the megaspore is sometimes called the *endosperm.* It is never exposed as in the Pteridophyta. The nucleus of the megaspore divides repeatedly till a large number of nuclei are present; these are arranged in a layer in the protoplasm lining the spore; then between them cell-walls are formed, and a peripheral cellular layer is thus constituted. The cells of this layer by ordinary cell-division produce a tissue which fills the spore. This is the prothallium. Archegonia are developed at its apical end, having almost the same structure as in the Pteridophyta. They arise from superficial cells, and have a neck and a venter, in which lie the neck-canal-cells, ventral-canal-cells, and oosphere respectively.

The microspore germinates upon the apex of the megasporangium. The pollen tube penetrates the latter by the micropyle and bores its way into the tissue of the nucellus during its development, as described above. The apex of the tube comes to the summit of the megaspore, where the necks of the archegonia are situated. It pierces the coat of the spore and either enters the neck of a single archegonium or spreads over several. A male gamete is extruded from the tip into the oosphere or oospheres as the case may be, and the nuclei of the two gametes fuse to form the nucleus of the new zygote.

This is the general arrangement throughout the group; but variations are found in some forms, particularly in the Gnetaceæ.

The fate of the zygote differs a good deal in the different Natural Orders of the group. The Coniferæ are the most regular, and may be first discussed. The embryo is derived from only part of the zygote; its nucleus goes down to the base of the cell and divides into two, and each of these into two; the four nuclei become four cells by protoplasm aggregating round them and cell-walls being formed between them. Each cell of the four divides twice transversely, so that instead of four cells there are four tiers, each tier consisting of three cells. Each of the middle cells grows out into a suspensor, the top cells of each tier attach the suspensor to the rest of the zygote, while the terminal cells give rise to four embryos.

This mode of development is that characteristic of the Abietaceæ; in the Cupressineæ a single tier of three cells is first formed; in *Thuja* only the two upper cells undergo longitudinal division, so that a single embryo is formed, furnished with four suspensor cells; in *Juniperus* all three divide as in the Abietaceæ. *Picea excelsa* of the Abietaceæ resembles *Thuja* in only forming one embryo instead of four. In the Cupressineæ the elongation to form the suspensor takes place in the top cell as well as the middle one.

Fig. 927.

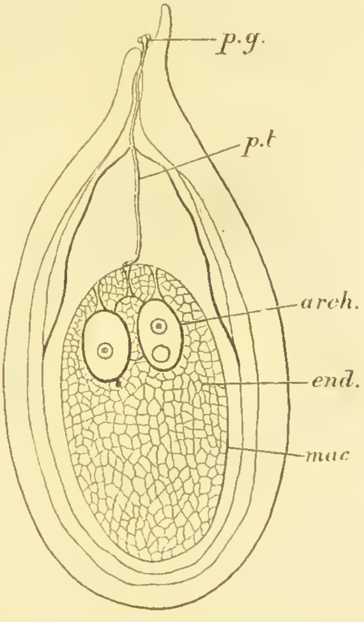


Fig. 927. Megasporangium (ovule) of *Pinus* at maturity. After Dodel-Port. *mac.* Megaspore. *end.* Gametophyte or prothallium. *arch.* Archegonia. *p.g.* Pollen grain or microspore, which has been transported to the micropyle of the ovule and has put out its prothallium, the pollen tube, *p.t.*

In the Cycadeæ the embryo is formed by a process of free-cell formation leading to the construction of a mass of cells, the lower part of which grows out into the tissue of the prothallium, forming a suspensor, at the end of which an embryo is developed. *Ephedra* of the Gnetaceæ behaves similarly, but each embryonic cell grows out separately in the same way, and so several embryos are formed; in *Ginkgo* the mass of cells formed in the zygote constitutes the embryo, and there is no suspensor. Other modifications occur in *Welwitschia* and *Gnetum*.

In most cases the zygote gives rise to a number of embryos; in the ripe seed, however, only one is usually present, the others perishing in the course of development.

The seed is always albuminous; a good deal of the prothallium persists, forming an endosperm, and a certain amount of the original nucellus is also present, forming perisperm. The embryo is found embedded in the endosperm: it consists of an axis, with plumule and radicle, and bears a variable number of cotyledons, sometimes only one, sometimes as many as fifteen. The growing point of the root is peculiar, being differentiated in the body of the embryo, some distance from its lower end. The integument of the megasporangium becomes hard and woody and forms the testa of the seed.

Fig. 928.

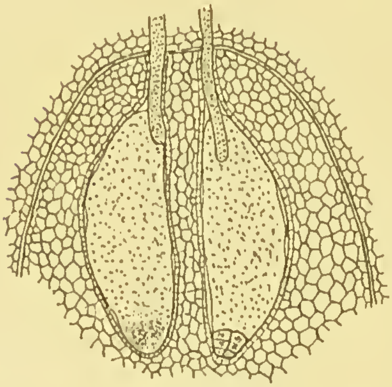


Fig. 928. Beginning of development of embryo in *Pinus*. The right-hand ovum is a little the more advanced.

The megaspore remains in the sporangium or ovule all the time these changes are proceeding, and the sporangium does not become detached from the sporophyte from which it originated. The resulting structure is the seed whose composition has just been described. In this body we have consequently three generations represented. From the original sporophyte are derived the testa, the perisperm or nucellus of the megasporangium, and the embryo sac or megaspore. From the gametophyte we have the endosperm or prothallium. From the zygote, the commencement of the new sporophytic generation, we have the embryo, which is the young sporophyte itself.

The Gymnosperms, are considered to be lower in the scale of development than the Angiosperms, and to approach the Pteridophyta in some points more closely than they do the former. This is particularly the case in the history of their gametophytes, which differ in hardly any respect from those of *Selaginella* except that they are entirely endosporous. Their origin from Cryptogamic ancestors is indisputable, but the exact line of descent is uncertain. There are many points which suggest that they may not all have developed along the same line. The Conifers show great resemblances to the Lycopodinæ. but the Cycads resemble the Ferns in many important respects. Certain fossil plants have been discovered which exhibit affinities with heterosporous ferns on the one hand and with recent Cycadeæ on the other, and which have consequently been called *Cycadofilices.*

The direct relations between Gymnosperms and Angiosperms are also obscure. There is no great reason to suppose that the latter have descended from the former.

The Gymnosperms are subdivided into three large classes, the *Cycadeæ*, the *Coniferæ*, and the *Gnetaceæ*, of which the first named appears to be the oldest. These groups have frequently been described as Natural Orders, but they are certainly not groups of such minor importance as the Natural Orders of the Angiosperms, which will be described in a subsequent chapter. For the present we may regard them as sub-classes.

Sub-Class I.—CYCADEÆ.

These are plants which resemble the Tree Ferns in their habit. but their leaves show an external similarity with those of the Palms. Their stems are not very tall, and are unbranched, bearing a crown of pinnate leaves, which are circinate in vernation. Besides these, the stems bear a number of closely-set scaly leaves, which cover their surfaces. The flowers are of two kinds, staminate and pistillate. The staminate flowers recall to some extent the arrangement of the sporangia of *Equisetum*, being usually a large collection of stamens or microsporophylls, arranged in cones. The pollen sacs are situated on the backs of the sporophylls, in *Cycas* itself being grouped in sori. The pistillate flowers, in all the genera except *Cycas*, also form cones, each megasporophyll being a peltate scale and bearing two ovules or megasporangia on the side nearest the axis. In *Cycas* there is no pistillate flower ; a whorl of megasporophylls taking the place of a whorl of foliage leaves. These are pinnate, and a number of the lower pinnæ are replaced by the ovules, which are of considerable size. The seeds are large and contain a single embryo, embedded in endosperm and attached to a coiled-up filamentous suspensor. They are covered by a testa, which has a succulent external layer, and inside it a horny one. There is only one Natural Order, the *Cycadaceæ*.

Sub-Class II.—CONIFERÆ.

This group includes the Pines, Firs, Cypresses, Yews, &c. They are usually trees which exhibit monopodial branching of the trunk, so that they attain a considerable height and are often beautifully pyramidal in form. They differ very markedly in appearance from the Cycads. The long branches or shoots in which the branch system terminates are crowded with small, often acicular leaves. In some genera these leaves are arranged directly on the long shoots, in others they are borne in small fascicles of leaves upon a very short branch. The number of leaves in each short branch may be two or may be several; the collection is known as a dwarf shoot, and is covered at its base by brown or withered scales. In other genera, again, leaves arise upon both long and dwarf shoots. The leaves are evergreen and do not show the ordinary dorsiventral structure. They belong to the type of centric leaves, described in a preceding chapter.

The flowers are in some cases monœcious, in others diœcious; they have no perianth. The staminate flowers are grouped together in very short catkins or cones, and consist in the latter case of a number of flattened or concave sporophylls, imbricated closely round a short axis. Each sporophyll bears typically two pollen sacs or microsporangia on its under surface. In *Taxus* each sporophyll is branched and bears five to eight pollen sacs on its under surface (*fig.* 932). The pistillate flowers are usually woody cones, consisting of an axis round which are arranged spirally a large number of imbricated sporophylls. From the base of each of these, or in its axil, arises a large scale, on the upper surface of which are arranged two orthotropous ovules. The morphology of the scale has been very much disputed, but it appears probable that it should be regarded as a placental development. Some writers consider it to be the modified outer integument of the ovule, which indeed has only a single coat. In the *Abietaceæ* these ovuliferous scales grow after fertilisation into large woody structures, which are usually much more conspicuous than the sporophylls. Their upper parts become hard and woody, and completely hide the sporophylls from sight. In the *Taxoideæ*, on the other hand, these ovuliferous scales are wanting. In some genera, as *Juniperus*, the cone instead of being woody becomes succulent. In most of the *Taxoideæ* the ovules are borne at the end of a branch of the axis, either singly or in pairs, and in some cases, as in *Taxus*, are surrounded when ripe by a fleshy aril.

Pollination is always effected by the agency of the wind; the pollen grains of some species are furnished with two bladder-like outgrowths, which facilitate this mode of dissemination. In those genera whose pistillate flower is a cone, the period of the dispersion of pollen sees a change in the degree of compression of the megasporophylls, the latter becoming a little farther apart from each other, so that pollen falling on the cone can reach the ovules. The pollen grain passes actually through the micropyle to the nucellus, the micropyle being considerably dilated to admit it. Subsequently the integument closes to a certain extent over the pollen grain, pressing it to the surface of the nucellus. This little space below the micropyle is often called the *pollen chamber*.

FIG. 929.

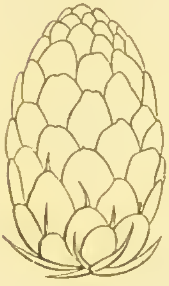


FIG. 930.

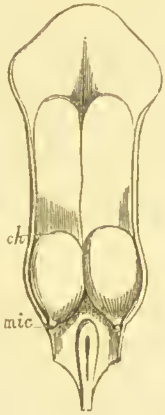


FIG. 931.

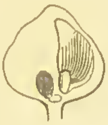


Fig. 929. A ripe cone of the Larch (*Pinus* [*Abies*] *Larix*). —*Fig.* 930. A mature ovuliferous scale of the Scotch Fir (*Pinus sylvestris*), with two winged naked seeds at its base. *mic.* Micropyle. *ch.* Chalaza.— *Fig.* 931. A scale of the Larch bearing one naked winged seed; the other seed has been removed.

The germination of the pollen is very slow, and the penetration of the tissue of the nucellus by the pollen tube takes a long time, which varies, however, in different genera. In some a month suffices, in others a year elapses before fertilisation is complete, the growth of the pollen tube taking place in two stages. At the time of pollination the ovule is altogether immature. During the growth of the pollen tube the development of the prothallium is completed and the archegonia and oospheres are matured. In a very large number of cases several oospheres are fertilised, and consequently several embryos are formed. One of them only, however, persists, except occasionally in *Ginkgo*. The embryo has usually several cotyledons.

The Coniferæ can be subdivided into two large groups or families, the *Pinoideæ* and the *Taxoideæ*, the former embracing several Natural Orders.

PINOIDEÆ.—The plants of this family usually bear their sporangia in cones, which are generally woody. The ovules are seated on the upper faces of the ovuliferous scales, which arise from the megasporophylls. The seed has a hard testa and is not furnished with an aril.

The principal Natural Orders included in this group are the *Araucariaceæ*, the *Abietaceæ*, which includes the Pines and the Firs, the *Taxodiaceæ*, and the *Cupressineæ*, or Cypresses.

Order 1. ARAUCARIACEÆ.—A small family of Malayan, Australian, and South American plants. The ovules are solitary, and the microsporangia free. The leaves are arranged in a close spiral.

Order 2. ABIETACEÆ.—The plants of this family include the Pine trees and Fir trees. They are pyramidal trees, exhibiting monopodial branching; the leaves are arranged in spirals, and are awl-shaped and taper generally to a sharp point. Some bear their leaves on dwarf shoots. The flowers are monœcious, and the placental or ovuliferous scale is very conspicuous; after ripening it sometimes forms two wings to the seeds. The embryo has usually five to fifteen cotyledons.

Dwarf shoots are present in the genera *Larix*, *Cedrus*, and *Pinus*, but are absent from *Abies* and *Picea*. *Abies* is peculiar in that the megasporophylls and their attached placentas separate from the axis after ripening. The leaves of *Larix* fall off much sooner than those of the other genera, and the dwarf shoots produce a new supply annually. The dwarf shoots of *Pinus* last for not more than three years; they bear the only green leaves of the tree, the long shoots carrying scales.

Order 3. TAXODIACEÆ.—The phyllotaxis is spiral throughout; the megasporophylls bear two to nine ovules on a pectinate placental scale.

Order 4. CUPRESSINEÆ.—The plants of this family have much smaller leaves, which are arranged usually in whorls. The flowers are diœcious in *Juniperus*, monœcious in *Cupressus*. The microsporophylls are peltate, and have several pollen sacs on their under surfaces. The pistillate cone is short and almost globular; the separate sporophylls fitting closely together by their edges. The placental scale is not distinct from the sporophyll, which is almost peltate in shape, and bears on the surface which is towards the axis of the flower, one, two, or more ovules. The fruit in *Cupressus* is termed a galbulus; it is hard and woody like the cone. When mature the sporophylls separate from each other all along their edges, allowing the seeds to fall out. In *Juniperus* the sporophylls become succulent.

TAXOIDEÆ.—The megasporangiate flowers are not cones; the ovules are often naked and terminal; the seeds are surrounded by an aril or have a succulent testa; the plants are usually diœcious.

There is only one Natural Order, the *Taxaceæ*, which is represented in Britain by the Yews. The ovule is terminal in this group, and underneath it are two to three pairs of bracteoles. As the seed matures an aril grows up round it, which is fleshy and sweet, and of a rich scarlet colour (*fig.* 933). The staminate flower (*fig.* 932) consists of a short axis, branched at the apex and bearing five to eight pollen sacs. A whorl of bracteoles occurs at its base.

FIG. 932.

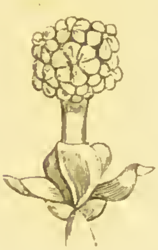


FIG. 933.

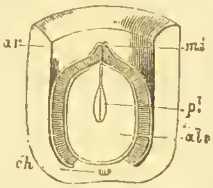


Fig. 932. Staminate flower of the Common Yew (*Taxus baccata*).——*Fig.* 933. Vertical section of the seed of the same. *ar.* The succulent cup-shaped mass which surrounds the seed. *pl.* Embryo. *alb.* Albumen. *ch.* Chalaza. *mi.* Micropyle.

One of the families of the Taxaceæ, the *Cephalotaxeæ*, includes the curious genus *Ginkgo*, which has fan-shaped leaves on long stalks. The ovules arise normally in pairs, and the seeds have no aril. The seed is separated from the parent plant soon after fertilisation, and its development is completed independently. At the time of severance it contains no embryo.

Sub-Class III.—GNETACEÆ.

These are in many respects the most highly developed of the Gymnosperms. The sub-class includes the three genera, *Gnetum*, *Welwitschia*, and *Ephedra*, which are strikingly unlike each other in appearance, but which agree in having a rudimentary perianth to their pistillate flowers. The megasporangia which are included in this perianth are axial in position, as they are in *Taxus*. They differ from the Coniferæ in having two cotyledons to the embryo, and in exhibiting true vessels in their secondary wood.

There is only one Natural Order, the *Gnetaceæ*.

Welwitschia has a short thick stem projecting a very little way above the soil ; it bears a pair of opposite oblong, very long, leathery leaves, which are usually much torn. In the axils of these the plant bears both staminate and pistillate cones. *Ephedra* has long slender jointed stems, giving it a bushy habit. The leaves are very small, and are united into a sheath round the stem, giving the plant a superficial resemblance to an *Equisetum*. *Gnetum* has opposite leaves, lanceolate in shape, with pinnate venation.

DIVISION B.—ANGIOSPERMÆ.

In this division the evolution of the flower reaches its highest point; the micro- and megasporophylls are usually found in the same flower; the former are, as a rule, much modified in shape, and their foliar character is at first sight difficult to grasp; they form the structures described already as *stamens*, each consisting normally of a *filament* and an *anther*, the latter bearing the microsporangia or pollen sacs. The megasporophylls are carpels, and are either distinct or coherent together. In either case the ovules or megasporangia are contained in a closed cavity, or ovary, formed by the cohesion in various ways of the carpellary walls. Each ovary is crowned by a *stigma*, which is often separated from the ovary by a filiform structure called the *style.*

The pollen grain, instead of entering the micropyle of the ovule and germinating there, falls upon the stigma and there develops its gametophyte, which penetrates the tissue of the style in the form of the pollen tube and makes its way into the cavity of the ovary, ultimately reaching the ovules. It generally enters the latter at the micropyle and so makes its way to the gametophyte of the megaspore or embryo sac, which is situated just below the micropyle. In a few cases it finds its way to the female cell by burrowing through the tissue of the ovule and of the gametophyte from the chalazal end. This, however, is exceptional, and only occurs in a few families.

The gametophyte produced by the megaspore is always completely internal or endosporous, and is very much reduced. It bears the female cell or oosphere at its micropylar end, and this cell is not enclosed in an archegonium (*fig.* 934).

Histologically the group shows an advance upon the structure of the Gymnosperms in the greater variety of the elements composing the wood and bast. The wood contains true vessels, which show the varieties of thickening already described. The sieve tubes always have companion cells. The development of the spores takes place in the way already described. In a few cases modifications of the process are found. In *Asclepias* and *Zostera* the mother cells of the pollen do not form four special mother cells, but each becomes a microspore.

The Gametophyte.—As in the Gymnosperms we have two forms of the gametophyte, the one coming from the microspore, the other from the megaspore.

The prothallium developed from the microspore is more reduced than in the last group. When the spore is shed, or sometimes while it is still in the sporangium, the nucleus divides into two, but this division is not followed by the formation of a cell-wall. The protoplasm of the spore aggregates round the two nuclei, forming two *primordial* or naked cells of unequal size, one of which is the *generative*, the other the *vegetative* cell. The exine ruptures, often at particular spots, but sometimes irregularly, and the intine grows out into a long tube, the *pollen tube*. In some cases, as in the Malvaceæ, several tubes arise from different points on the spore.

The pollen tube is derived from the larger of the two cells, the vegetative one, as in the Gymnosperms. The generative cell passes into the tube, as does the vegetative nucleus. As they proceed down the tube, the generative cell divides into two, forming two gametes, which correspond to the antherozoids of lower forms, but they are never differentiated as in the latter case. The vegetative nucleus becomes disorganised and disappears.

By the time that the pollen tube has reached the gametophyte of the megaspore the process is complete, and the tube remains with its two gametes at or near its apex. The protoplasm of the tube is richly vacuolated, and the granules it contains show extensive movements of circulation.

The megaspore produces its gametophyte in its interior as in the Gymnosperms, but the prothallar tissue is very much smaller (*fig.* 934). The nucleus of the megaspore divides into two, and each travels to one end of the spore. Each then divides into two, and each of the daughter nuclei repeats the process, so that at that stage the spore contains two groups each of four nuclei, one at the micropylar and the other at the chalazal end. One nucleus from each of these groups, the so-called *polar* nucleus, then travels to the centre of the spore, and the two fuse together, constituting what is known as the *definitive nucleus* of the embryo sac. A certain amount of protoplasm aggregates round each of the three nuclei at the two ends, forming two groups of three cells each. Those at the chalazal end secrete cell-walls and form the *antipodal cells*, which take no further part in the development; those at the micropylar end remain naked and constitute the *egg apparatus*. One of these, whose nucleus is the sister nucleus of the one which descended to help form the definitive nucleus, is the female gamete, or *oosphere*, while the other two are known as the *synergidæ*. In some few cases the definitive nucleus is constituted by only the one from the chalazal end; there are then two oospheres, of which only one becomes fertilised. In rare cases the synergidæ are fertile gametes, though this very seldom happens.

At this stage the development of the prothallium remains suspended, and nothing further takes place unless the oosphere becomes fertilised. The egg apparatus lies almost always immediately below the micropyle, and is thus not covered by a mass of tissue as in the Gymnosperms. The pollen tube reaches the micropyle as already described; its apex becomes more or less mucilaginous, as does the wall of the embryo sac, and one of the male gametes makes its way through to the oosphere, with which it fuses, nucleus with nucleus and protoplasm with protoplasm. The fertilised oosphere, now become a zygote, surrounds itself with a cell-wall, and the synergidæ become disorganised and disappear.

Fig. 934.

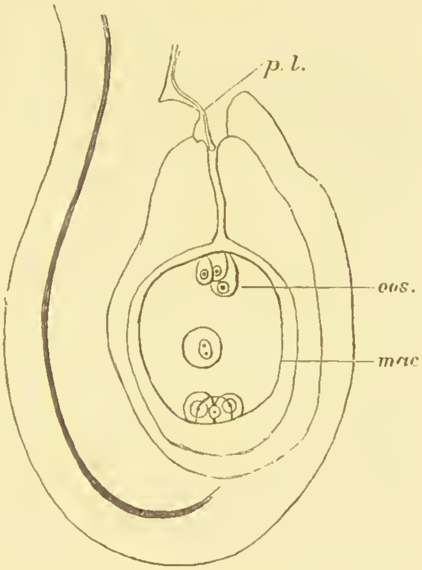


Fig. 934. Megasporangium (ovule) of an Angiosperm. *mac.* Megaspore. *oos.* Oosphere. *p.t.* Pollen tube.

The further fate of the zygote differs in the two classes into which the Angiosperms are divided and will be discussed later.

The embryo sac becomes filled with a tissue known as the *endosperm*, which has, however, a different morphological value from the tissue in the megaspore of the Gymnosperms, though it bears the same name.

This so-called endosperm is derived from the definitive nucleus of the embryo sac. Its formation has been seen in several species to be preceded by the fusion of the second male gamete from the pollen tube with the two polar nuclei or their product, the definitive nucleus. The resulting nuclear body, or the definitive nucleus alone if this fusion does not occur, divides repeatedly, forming a number of nuclei which become disposed in a layer all over the surface of the wall of the embryo sac. Round each of these an aggregation of protoplasm takes place, so that the sac has a lining of naked or primordial cells. These become separated from each other and from the cavity of the spore by cell-walls, and the cells so formed divide repeatedly till, in most cases, the part of the embryo sac not occupied by the body resulting from the divisions of the zygote becomes filled with a mass of tissue, which is this so-called endosperm. In a few cases the endosperm does not completely fill the spore, but leaves a hollow cavity in the centre.

The young embryo, derived from the zygote in a manner still to be explained, together with the endosperm and the remains of the microsporangium and its coats, forms the body frequently alluded to above as the *seed*. The coats or integuments of the megasporangium generally become hard and form the *testa* of the seed.

In some cases the endosperm is not formed by free-cell-formation as described above, but by ordinary cell-division, walls being developed after each nuclear fission.

In many plants this condition of things persists, and the embryo in the ripe seed is embedded in the endosperm. In others the embryo grows vigorously, and in its enlargement absorbs the contents of the endosperm cells. The seed then shows only the embryo surrounded by the testa. Generally the seed leaves or cotyledons are the parts which form the bulk of the embryo in such cases.

When fertilisation has been effected, and the zygote is formed, it at once commences its further development. There is no pause between the maturity of the gametophyte and the origination of the new sporophyte. A resting period occurs later, when the young plant has attained a certain size and when the endosperm has been formed and perhaps absorbed. The zygote divides into two by a transverse wall, and the two cells so formed, which correspond to the epibasal and hypobasal cells of the Pteridophyta, give rise, as in the latter case, to different structures. The hypobasal segment, which is the one nearest to the micropylar end of the embryo sac, develops into a chain of cells known as the *suspensor*, a structure noticed as occurring in a similar manner in the embryogeny of the Lycopodinæ. The suspensor does not become free from the protoplasm of the embryo sac, in which the oosphere was originally placed, and hence attaches the embryo to the embryo sac in a way indicated by the name *suspensor*. The suspensor, as a rule, soon perishes, so that only traces of it can be seen in the seed; sometimes, however, it grows to great length. In the Orchidaceæ cases occur where it assumes such a size as to make its way out of the embryo sac through the micropyle and to ramify in the interior of the ovary and the tissue of the placenta. In some Dicotyledons a somewhat similar behaviour is found. In such cases it recalls physiologically as well as morphologically the *foot* of the Ferns and their allies, absorbing nutriment for the support of the embryo.

The suspensor contributes a cell to the formation of the embryo in a manner to be described below.

The epibasal cell, often termed the *embryo cell*, divides very differently. In it three walls are formed successively at right angles to each other, dividing it into eight octants. The octants in this group, it will be noticed, all proceed from the epibasal cell only and not from the whole zygote as in the Ferns &c. The recent separation of the hypobasal cell causes the epibasal one not to be a sphere as is the zygote, so that the octants next the suspensor are partially flattened and abut upon the latter in a somewhat truncated fashion. The subsequent divisions differ a little in the Dicotyledons and the Monocotyledons. In the former group the anterior octants give rise to the upper portion of the axis, but the posterior ones only form the hypocotyl, the primary root being formed from the last cell of the suspensor, the so-called *hypophysis*. In the latter group this cell gives rise to the growing point of the laterally produced stem, and the root originates in the segment of the hypophysis next to the rest of the suspensor.

When the octants have been formed, the next step in the development is the formation of the dermatogen by walls parallel to the surface of the embryo. At first the dermatogen is incomplete, the periclinal walls only being formed in the octants, but it is soon continued across the hypophysis, which has by this time grown up in a slightly bulging fashion at the base of the embryo (*figs.* 935 and 936). Of the cells so formed from the hypophysis the internal one gives rise to the periblem of the root, while the latter forms its dermatogen, which soon becomes many-layered and constitutes the root cap. The further growth of the embryo soon gives rise to the three systems of tissue already described, the *dermatogen*, *periblem*, and *plerome*.

In the Monocotyledons the terminal cotyledon is developed from the octants, the hypophysis dividing to form a row of cells, of which the anterior ones give rise to the stem, while the posterior one forms the root, as the whole hypophysis does in Dicotyledons. The order of division of cells is very similar, and the embryo becomes differentiated histologically in the same way. The young stem is derived from the upper cell of the two resulting from the first division of the hypophysis, and as it assumes its form it turns out laterally from below the cotyledon.

Fig. 935.

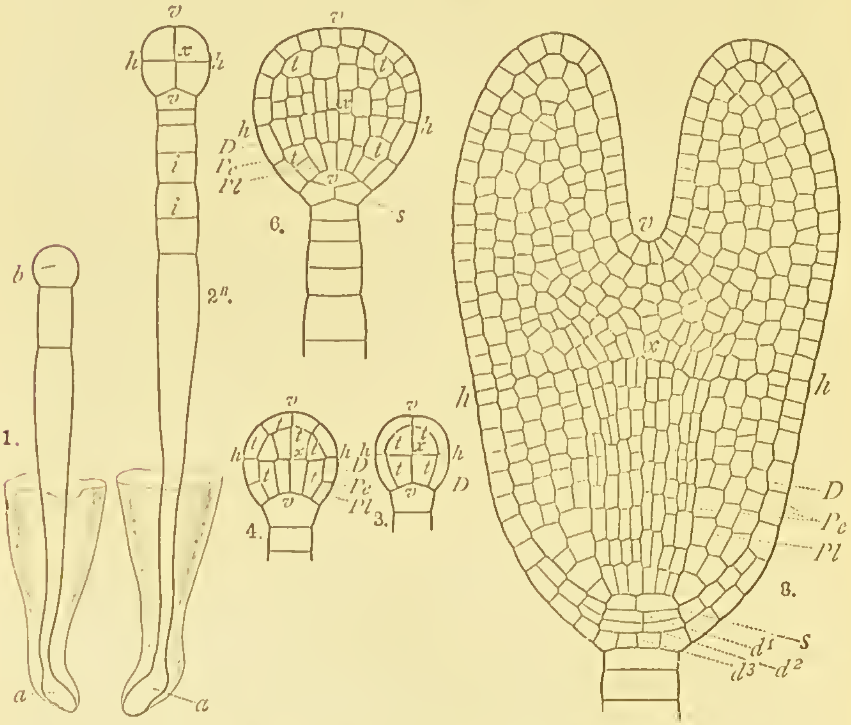


Fig. 935. Successive stages in development of the embryo of *Brassica*. After Kny.

This division of the Phanerogamia includes the two classes of Monocotyledons and Dicotyledons, which are distinguished from each other by the following points :—

Monocotyledons.—The embryo has a single cotyledon, which is placed at its apex, while the plumule arises laterally; the flower is usually trimerous; the vascular bundles do not contain cambium and are small and arranged in a scattered manner in the stele; the foliage leaves usually have parallel venation.

Dicotyledons.—The embryo has two cotyledons, between which the plumule is developed; the vascular bundles are arranged in a circle in the stele and usually increase in thickness by means of a cambium layer; the flower is either tetramerous or pentamerous; the foliage leaves usually have reticulate venation.

Fig. 936.

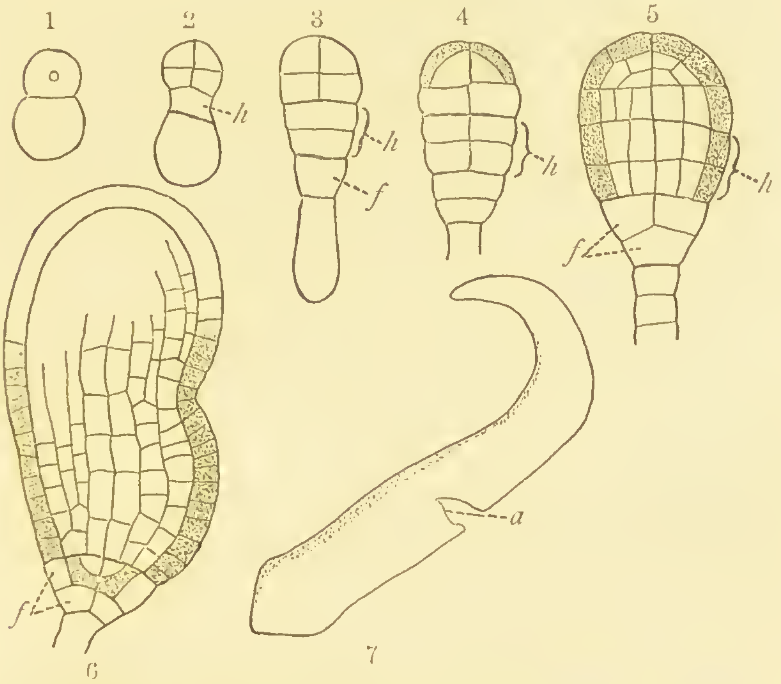


Fig. 936. 1, 2, 3, 4, 5, 6. Successive stages in the development of the Monocotyledonous embryo of *Alisma*. *h*. Hypophysis and the cells derived from it. *f*. Segment of the hypophysis which gives rise to the root. 7. Mature embryo. *a*. Apex of stem. After Sachs.

CLASS X.—MONOCOTYLEDONES.

The general histology as well as the morphology of this group has been already treated of in some detail.

As has been mentioned in an earlier chapter, these plants have been classified in different ways. A scheme which has been adopted in England by Vines divides them into three large sub-classes, the *Spadicifloræ*, the *Glumifloræ*, and the *Petaloideæ*. Of these the first is characterised by having a spadix as the typical form of inflorescence, the second by having the flowers in heads or spikelets and the perianth absent or scaly, and the third by having usually a petaloid corolla and sometimes a petaloid calyx. The Natural Orders which fall under these divisions are further grouped together in cohorts, as already shown.

Though other systems of classification are adopted by different writers, all agree fairly closely in the general scheme of Natural Orders into which the genera are collected. Divergences are only apparent when the classification of the Natural Orders is undertaken.

By Bentham and Hooker, whom in the main we follow in this treatise, these Natural Orders are collected together into seven series in the manner now to be described.

Series 1.—*Microspermæ*.

These plants have usually a biseriate perianth, of which the inner whorl at least is petaloid. The ovary is inferior, 1-celled with three parietal placentæ, or 3-celled with axile placentæ. The seeds are very small and numerous, and they have no endosperm.

Order 1. HYDROCHARIDACEÆ.—The plants of this order are aquatic in habit, some being entirely submerged, others having floating leaves. The inflorescence is surrounded by a large spathe, which is formed either of a single bract or of two bracts which are connate. The flowers are diœcious. The perianth usually consists of both calyx and corolla, the latter being coloured. The stamens are typically in two whorls of three each but may be more numerous by multiplication of whorls. The pistillate flowers have staminodes and an inferior ovary, which in most cases is 1-celled with parietal placentation. The carpellary leaf-edges in some cases protrude into the ovary, making it more or less plurilocular. The fruit is succulent.

Hydrocharis Morsus-ranæ, the Frog-bit, has runners bearing tufts of stalked entire reniform leaves. *Stratiotes* creeps on the mud at the bottom of streams; the plant rises to the surface of the water to flower, and sinks again afterwards. It has sword-shaped narrow leaves. *Vallisneria* is a sub-tropical genus; its staminate flowers become detached from the plant and rise to the surface of the water, where they pollinate the pistillate flowers. The latter are borne on long spirally-twisted peduncles, which elevate them above the surface. After being pollinated the stalks contract and the flowers sink. The fruit ripens under water. *Elodea* (*Anacharis*) is a submerged form, which bears whorled leaves. Its reproduction in Europe is entirely vegetative, as the staminate plants are not known. The plant was introduced from North America.

Order 2. BURMANNIACEÆ.—A small order of tropical herbs, some of which are saprophytic in habit. They have a 6-leaved perianth, which in some cases is labiate. The ovary is inferior, and most generally 1-celled with three parietal placentæ. The seeds are numerous.

Order 3. ORCHIDACEÆ.—The plants of this order are all herbaceous, but show a very great variety in their habits and their morphological structure. Many of them are epiphytic, and are furnished with long aerial roots; others are terrestrial, and bear two tubers or tuberous roots at the base of a small flowering stem or scape; others again are saprophytic and bear ramifying rhizomes, true roots being absent. Most of them have no sub-aerial stem, but in some forms there is a very short one, much swollen, and consisting of a single internode, or at most of two; this is known as a *pseudo-bulb*.

The inflorescence in most cases is a raceme, which may be closely compressed or very lax. The flowers have frequently a curious twist in the long inferior ovary, which makes them inverted in position. They are strongly zygomorphic in an antero-posterior plane, the number, shape, and position of the parts being variously interfered with. There is a 2-seriate perianth, and the calyx is petaloid as well as the corolla. The sepals are superior and generally regular. The corolla is epigynous; it consists of three petals, one of which is posterior, being modified in shape and colour and forming a large, spreading, often 3-lobed leaf, called the *labellum*. By the twisting of the ovary already mentioned, it comes to lie anteriorly. Both the typical whorls of stamens of the Monocotyledons are represented, but differently in different genera. In most Orchids there is a single perfect stamen, which is the anterior one of the outer whorl, the other two of this whorl not being present, or, according to some morphologists, being displaced and becoming foliaceous and fusing with the labellum, of which they form the two lateral lobes. The inner whorl is in most cases entirely suppressed, but in some flowers is represented by two staminodes placed anteriorly. In some species these are petaloid, in others they appear as small swellings on the gymnostemium.

In the *Apostasieæ* there are either two or three perfect stamens. In the latter case these are the one anterior of the outer whorl and the two lateral of the inner one; in the former case only the latter two, the anterior one of the outer whorl being represented by a staminode. *Cypripedium* also has the last-mentioned arrangement. There are three carpels which cohere to form a monolocular inferior ovary, with usually parietal placentation.

FIG. 937.

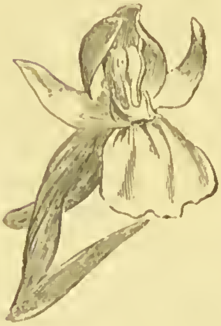


FIG. 938.

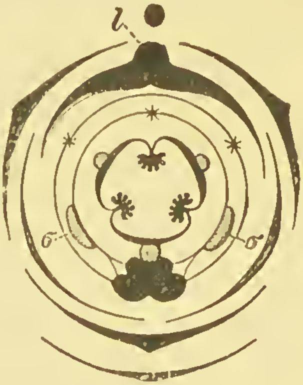


FIG. 939.

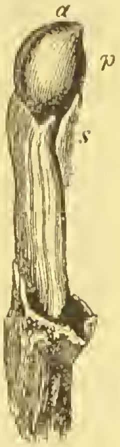
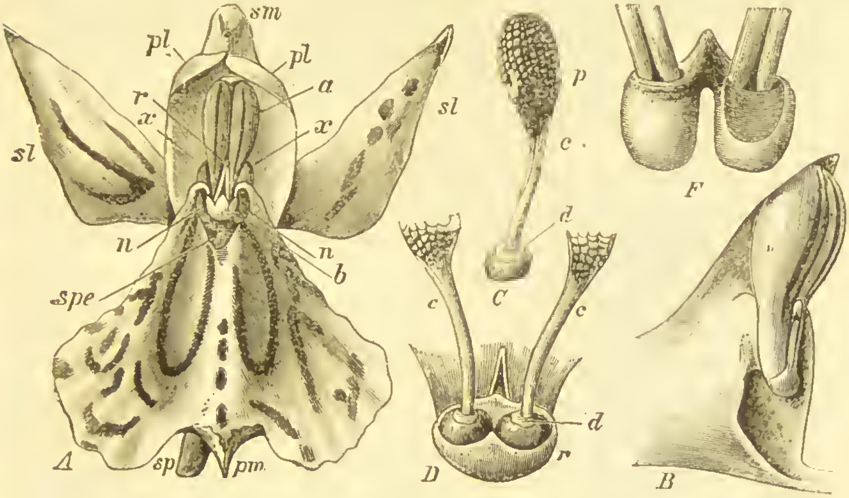


Fig. 937. Flower of *Orchis mascula*. — *Fig.* 938. Diagram of the flower of *Orchis*. — *Fig.* 939. Stylar column of *Cephalanthera*. *a*. Anther. *s*. Stigma. At the foot are seen scars indicating the position of parts that have been removed. After Warming.

The appearance of the interior of the flower is very peculiar, in consequence of curious adhesions between the stamens and the styles. In the centre there is found a curious columnar body, which is formed by the union of the filament of the single stamen with the styles of the three carpels. It is known as the *gymnostemium*. The two lateral stigmas form a horseshoe-shaped sticky depression on this structure just below the anther, and the third is either rudimentary or is developed into a curious prominence known as the *rostellum*, which projects just below the stigmatic surface. In most Orchids the whole mass of pollen contained in each pollen sac is coherent, and from either the upper or the lower end of each mass or *pollinium* a mucilaginous stalk or filament proceeds, which is usually enclosed in a slit-like pouch. This mucilaginous thread is secreted by the tissue of the anther, and is called a *caudicle*. Each caudicle is continuous at its base with a similarly composed disc, which is formed in a small depression or cup in the rostellum. When the rostellum is touched, if the pollinium is mature it is removed by the sticky disc at the base of the caudicle being jerked forward and adhering to the intruding body.

Fig. 940.



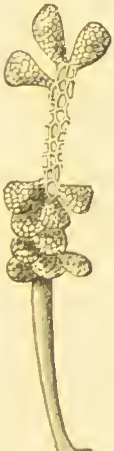


Fig. 940. *A.* Flower of *Orchis maculata* (front view). *a.* Stamen. *b.* The cup. *n.* The stigmas. *x.* Staminodes. *sp.* The spur. *spe.* The entrance to it. *sm, sl, sl.* Exterior perianth leaves. *pm.* The labellum. *pl, pl.* The other two interior perianth leaves. *B–E. Orchis mascula. B.* Lateral view of the column. *C.* A pollinium with massulæ (*p*), caudicle (*c*), and adhesive disc (*d*). *D.* Caudicles with the cup (*r*), front view; the latter is depressed so that the adhesive disc is seen lying inside it. *E.* A pollinium more highly magnified; some massulæ are removed. *F. Ophrys aranifera*; rostellum and the base of the anther loculus; an adhesive disc is seen on the right. After Warming.

The pollen is not coherent into pollinia in all the genera.

In *Neottia* the grains are united in tetrads or groups of four; in some genera they are united into larger masses, known as *massulæ*, which are connected together by elastic threads.

In the Apostasieæ and the Cypripedieæ the third stigma is present and functional together with the other two.

The seeds are very numerous and are attached to placentas, which in most genera are parietal. They are very small and contain no endosperm. The embryo is minute, almost spherical, and is morphologically entirely undifferentiated.

The order is divided into several tribes, the chief of which are the following:—

1. *Apostasieæ.*—This was formerly considered to be a distinct Natural Order. The perianth is regular, the stamens either two or three, as already described, and the pollen is not collected into pollinia.

2. *Cypripedieæ.* The flower has a remarkable slipper-shaped labellum. There are two stamens, which are the lateral pair of the inner whorl. The anterior stamen of the outer whorl is represented by a large shield-like body, which must not be confused with the rostellum of other tribes. The latter body is not represented, all three stigmas being functional. The pollen grains are distinct.

3. *Neottieæ.*—These are terrestrial Orchids, many of which are saprophytic to a greater or less extent. Some contain no chlorophyll. The pollen grains are united into loose pollinia; the *apex* of the anther is connected with the rostellum.

4. *Ophrydeæ.*—The anther is united to the rostellum at its *base*. The pollen is in pollinia.

5. *Leparidinæ.*—The anther produces four waxy pollinia without caudicles.

There are many other families, which are chiefly tropical epiphytes with aerial roots. A discussion of them would be beyond the scope of this work.

Series 2.—*Epigynæ.*

The plants of this series differ from those of the last chiefly by having abundant albumen, which may be perisperm or endosperm. In a few genera of Bromeliaceæ and Hæmodoraceæ the ovary is superior.

Order 1. Scitaminaceæ.—The plants of this order are tall and herbaceous, with large pinnately veined leaves. The flowers are irregular, zygomorphic, or unsymmetrical. The perianth is 2-seriate, and sometimes both whorls are petaloid. The stamens are typically six in two whorls, but in many cases there is a good deal of suppression in the andrœcium. The ovary is generally 3-celled, and the fruit may be a capsule or a berry.

The seed contains perisperm, but, except in the Zingibereæ, no endosperm. The order is divided into three tribes, which are often described as separate Natural Orders.

1. *Zingibereæ.*—There are two types of flower in this tribe. In the first the calyx is gamosepalous; the outer whorl of stamens is represented by two petaloid staminodes, the anterior one being aborted. There is a perfect stamen, which is the posterior one of the inner whorl; the other two of this whorl coalesce to form a large, sometimes lobed. foliaceous body, the *labellum.* In the second type of flower the staminodes of the outer whorl are absent.

2. *Museæ.*—The plants of this tribe are of enormous size and almost shrubby in habit. The leaves are very large and have long sheathing petioles, which together form by their union a spurious sub-aerial stem. The flowers are arranged spirally in spikes, in the axils of bracts which are frequently coloured. The flowers are pistillate at the base of the spike, become perfect in the middle, and are staminate at the top. The perianth is petaloid, the anterior leaf being very large and the posterior very small. The posterior stamen of the inner whorl is rudimentary or wanting. The fruit is a berry containing a farinaceous pulp. It is elongated like a pepo, and in the cultivated species contains no seeds.

FIG. 941.

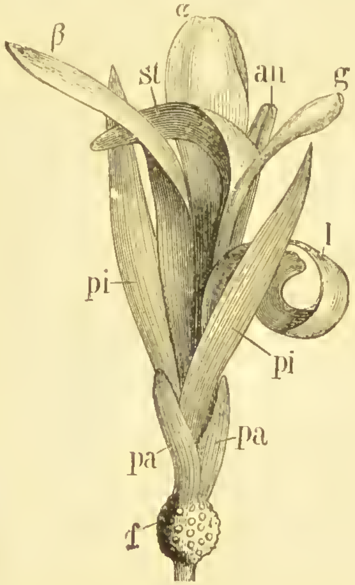


Fig. 941. Flower of *Canna.* *f.* Ovary. *pa.* Calyx. *pi.* Corolla. *l.* Labellum. *st.* Stamens. *an.* Anther. *g.* Stigma. α, β. Staminodes. After Warming.

3. *Maranteæ* or *Canneæ.*—The flower is asymmetrical, and the calyx is sepaloid. The posterior stamen of the inner whorl is in this tribe the only one which bears an anther, the other five becoming all staminodes; one of the latter is longer than the rest, and forms the labellum. All of them are foliaceous. The style also is petaloid (*fig.* 941).

Order 2. BROMELIACEÆ.—The plants of this order are woody or herbaceous; many of them are epiphytes, while others live in rocky places; a few are terrestrial. The stem is short and thick, and bears at its apex a rosette of large leathery leaves which are sheathing at the base and channelled all the way up; they close round each other completely, so that they hold a quantity of water in the hollows which are thus formed. The perianth is biseriate, and there are two whorls of stamens. The fruit is a capsule or a berry.

The best-known plant of this order is *Ananassa sativa*, the Pineapple. It bears a crown of leaves above the inflorescence, and its berries coalesce with one another and with their fleshy bracts to form a succulent sorosis. Under cultivation there are no seeds produced.

Fig. 942.

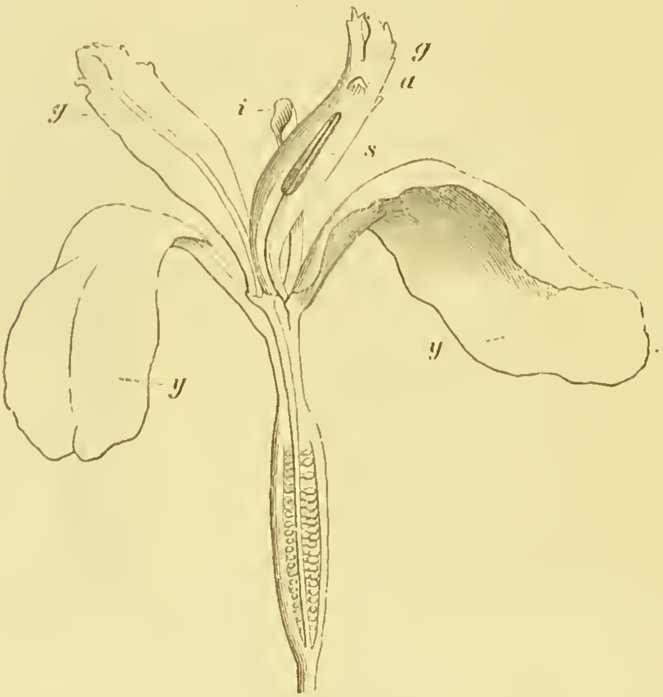


Fig. 942. *Iris pseudacorus.* One external and two internal perianth leaves have been removed. *y.* The outer, *i*, the inner, perianth leaves. *g.* Stylar branch. *a.* Stigma. *s.* Anther. After Warming.

Order 3. Hæmodoraceæ.—A small order of perennial herbs or shrubs, which have ensiform equitant leaves. They are a link connecting the Bromeliaceæ with the Iridaceæ.

Order 4. Iridaceæ.—The plants of this order are perennial herbs, whose stems are generally subterranean and take the forms of rhizomes or corms, and less frequently bulbs. In most species the leaves are equitant, and arranged in two ranks. The inflorescence in most cases is cymose, and there is usually present a spathe, which may invest several flowers or only a single one. The flowers are epigynous, and in some families zygomorphic; the perianth is 2-seriate, and both its whorls are petaloid. The antipetalous whorl of stamens is suppressed, so that the three carpels are opposite to the three stamens. The anthers are extrorse and are covered over by the foliaceous styles, which like the perianth leaves are petaloid. The stigma is a small triangular shelf-like body, situated a little below the tip of the style (*fig.* 942, *a*). The ovary is inferior, 3-celled, with axile placentation. The fruit is a capsule, which dehisces loculicidally.

FIG. 943.

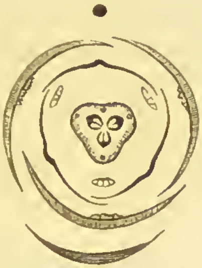


FIG. 944.

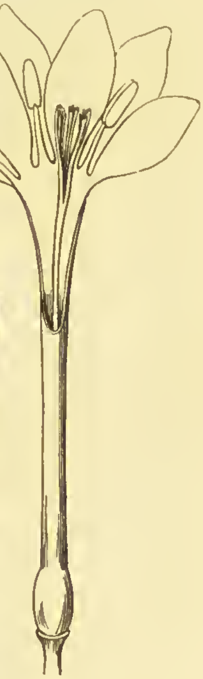


FIG. 945.

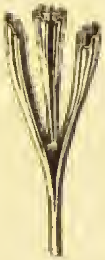


Fig. 943. Diagram of the flower of a species of *Iris*, showing solitary bract below, six divisions to the perianth arranged in two whorls, three stamens, and a 3-celled ovary with axile placentation.——*Fig.* 944. A flower of the Spring Crocus (*Crocus vernus*) cut open to show the three extrorse stamens attached to the outer segments of the perianth.——*Fig.* 945. The three petaloid stigmas of the same with the end of the style.

The order is divided into the following tribes :—

1. *Crocoideæ.*—The flowers are actinomorphic, each invested by a spathe; the stem is a corm.

2. *Iridioideæ.*—The flowers are actinomorphic, but each spathe invests more than one; the stem is a rhizome or a bulb.

3. *Ixioideæ.*—The flowers are frequently zygomorphic; the stem is a corm. Each spathe invests only a single flower.

In the pollination of the Iris flower the active agents are bees. Honey is found in the perianth tube; the insects, in their search for it, alight on the large sepals, which have a ridge of hairs just under the anthers. The latter are extrorse, and hence the pollen is discharged or collected on to the head or back of the bee. On withdrawal the latter cannot pollinate the flower, as the stigma is on the upper side of the little shelf (*a*, *fig.* 942). On visiting another flower while bearing pollen, the insect deposits it on the stigmatic surface above the shelf as it advances towards the honey tube.

The Iridaceæ are chiefly natives of temperate and warm climates. They are found in various parts of the globe, but are most abundant at the Cape of Good Hope. There are about 560 species.

The rhizomes of several species possess acrid properties, which causes them to be purgative, emetic, &c. Some are poisonous, and a few have fragrant rhizomes. Others are employed as colouring agents, and some are commonly regarded as antispasmodic, carminative, &c. Many contain starch in large quantities, but as this is usually combined with an acrid principle, they are not generally available for food.

Order 5. AMARYLLIDACEÆ.—The plants of this order are chiefly bulbous or rhizomatous plants, though in some genera there is a woody sub-aerial stem. The inflorescence is usually a scape bearing a number of flowers, though the latter are sometimes solitary. As in the Iridaceæ, there is usually a spathe surrounding the inflorescence. The flower has the typical Monocotyledonous structure, but it is epigynous. The perianth is usually petaloid throughout, both whorls of stamens are perfect, and there is a 3-celled inferior ovary with axile placentation. The fruit is usually a capsule, but in some species it is a berry.

The divisions of the order are the following:—

1. *Amaryllea.*—The plants have bulbs; the scape bears one terminal flower, or an umbel surrounded by an involucre.

Narcissus, the Daffodil, has inside its perianth a corona, which is sometimes very large and trumpet-shaped (*fig.* 947). This is considered to be formed by the union or cohesion of a number of *scales* or *ligules*, one of which is borne by each perianth leaf at the point of junction of the claw and limb. Coronas occur also in the flowers of the genera *Pancratium* and *Eucharis*, where they are united to the filaments of the stamens, giving the latter the appearance of being monadelphous.

2. *Agaveæ.*—These are very large plants with very thick, often thorny leaves borne upon a short thick stem. They are arranged in

a rosette. The plants do not flower till they have attained an age of several years, and the flowering is followed by the death of the shoot.

Fig. 946.

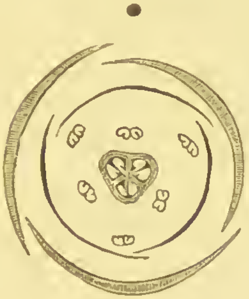


Fig. 947.

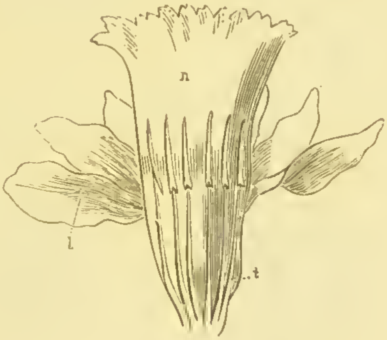


Fig. 948.

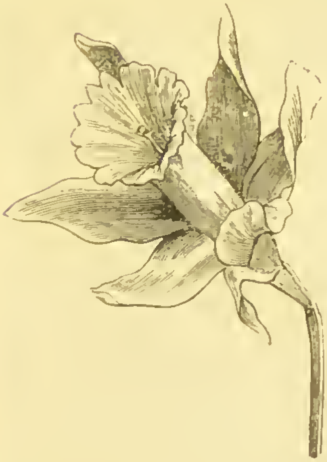


Fig. 949.

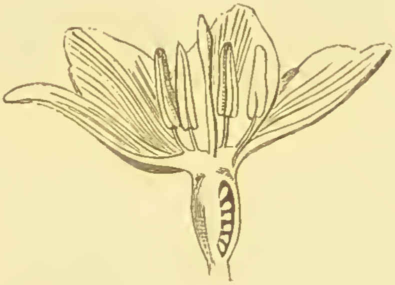


Fig. 950.

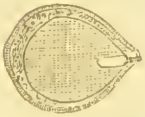


Fig. 946. Diagram of the flower of the Spring Snowflake (*Amaryllidaceæ*), with six divisions to the perianth arranged in two whorls, six stamens, and a 3-celled ovary with axile placentation.——*Fig.* 947. The perianth of the Daffodil (*Narcissus Pseudo-narcissus*) cut open longitudinally. *t.* Tube bearing six stamens. *l.* Limb of the perianth. *n.* Corona.——*Fig.* 948. Flower of the Daffodil, showing six perianth leaves, with the corona in the centre.——*Fig.* 949. Vertical section of the flower of the Spring Snowflake (*Leucojum vernum*).——*Fig.* 950. Vertical section of the seed of the same.

3. *Hypoxideæ.*—The plants have a subterranean rhizome which bears a terminal shoot. The leaves are often grass-like.

Several plants of this order possess poisonous qualities. This property is especially evident in *Hæmanthus toxicarius*, the juice of which is used by the Hottentots to poison their arrow-heads. Some yield excellent fibres. The juice of some few species is saccharine, and is employed in the preparation of fermented liquors. Starch may be obtained from certain species of *Alstrœmeria*. Some are bitter and aromatic. Medicinally, several have been used as emetics and purgatives.

Order 6. Taccaceæ.—A small order of tropical plants which have subterranean rhizomes; the leaves springing from these have reticulate venation. The filaments of the stamens are often petaloid; the ovary is 1-celled, with three parietal placentæ.

Order 7.—Dioscoreaceæ.—These are tropical plants which have usually a climbing habit, twining by their stems. They also possess tubers, which may be above or under the ground. The leaves have reticulate venation. The flowers are diœcious; the staminate ones have six stamens, and the pistillate ones three carpels; the perianth is 6-partite in both. The ovary is 3-celled, and bears usually two ovules in each loculus.

Tamus communis, the Black Bryony, is the only British species. It is a common climber in many parts of England. *Dioscorea*, the Yam, has frequently tubers in the axils of its leaves, as well as subterranean ones.

Series 3.—*Coronariæ*.

The plants of this series differ from those of the last mainly in having superior ovaries.

Order 1. Roxburghiaceæ.—A small East Indian order with dimerous symmetry. The ovary is 1-celled, with basal placentation.

Order 2. Liliaceæ.—The plants of this order are herbs, shrubs, or trees, of very varied habit. The forms of stem met with include bulbs, rhizomes, and tubers, as well as sub-aerial forms, which may be simple or branched. The leaves are usually large and sheathing at their bases; sometimes they are succulent. Their venation is generally parallel. The inflorescence is very varied, but is usually racemose in type. Solitary flowers are met with. In some cases a spathaceous membranous bract invests the inflorescence The flowers are regular, and, except in a few species, trimerous throughout. There are two perianth whorls, both of which are petaloid; two whorls of stamens and one whorl of carpels, all of which occur in regular alternation. The fruit is in some cases a capsule with loculicidal dehiscence; in others a usually 3-celled berry.

The order is a large one and comprises several tribes, some of which have been considered distinct Natural Orders. The chief of these tribes are the following:—

1. *Lilieæ.*—Bulbous or rhizomatous plants; the anthers are introrse, and the three styles and stigmas are united; the fruit is a loculicidal capsule.

Fig. 951.

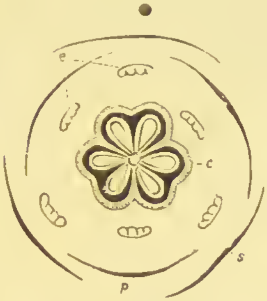


Fig. 952.

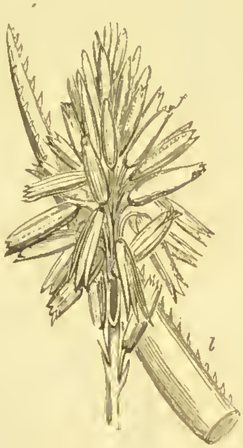


Fig. 954.

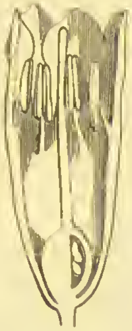


Fig. 953.

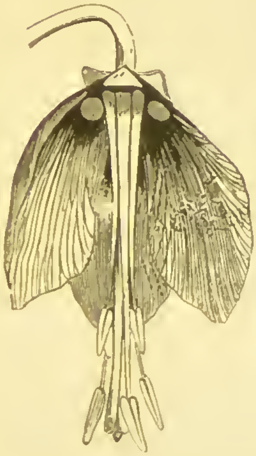


Fig. 955.

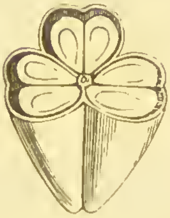


Fig. 956.

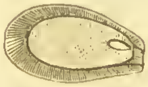


Fig. 951. Diagram of the flower of a species of Lily. *s.* The three outer divisions of the perianth. *p.* The three inner. *e.* The stamens. *c.* Three-celled ovary.——*Fig.* 952. Raceme of flowers *f*, and portion of the succulent leaf *l*, of a species of *Aloe*.——*Fig.* 953. Flower of the Crown Imperial (*Fritillaria imperialis*) with half the perianth removed.——*Fig.* 954. Vertical section of the flower of the Solomon's Seal (*Polygonatum multiflorum*).——*Fig.* 955. Transverse section of the ovary of the White Lily (*Lilium candidum*).——*Fig.* 956. Vertical section of the seed of the Crown Imperial.

The *Tulipeæ* and the *Scilleæ* are subdivisions of this tribe. In the former family the bulb throws up an elongated stem, on which the foliage leaves are borne. The flowers are generally large. The most conspicuous British genera are *Lilium*, *Tulipa*, and *Fritillaria*, the latter bearing a number of pendant flowers surmounted by a crown of leaves. In the *Scilleæ* the leaves spring directly from the bulb, the inflorescence being a scape.

2. *Melantheæ* or *Colchiceæ*.—The stem is generally a rhizome or a corm. The anthers are extrorse, and the styles are free. The capsule usually dehisces septicidally. *Colchicum autumnale* is the Meadow Saffron. It flowers in autumn without leaves, the latter appearing in spring. Its stem is a corm, from which the new plant springs as a lateral shoot. This tribe approaches the *Lilieæ* in the genera *Narthecium* and *Tofieldia*, the former having a solid style and the latter introrse anthers.

Fig. 957.

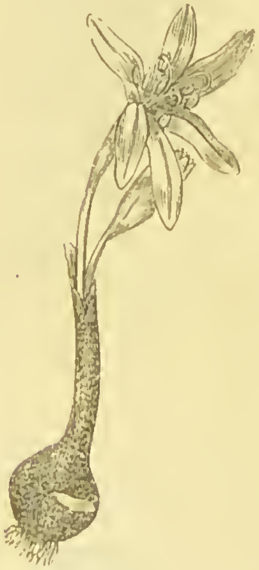


Fig. 958.

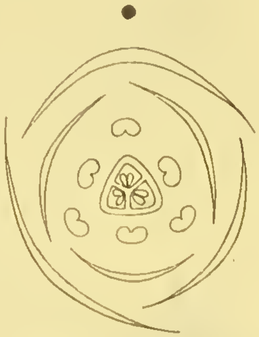


Fig. 959.

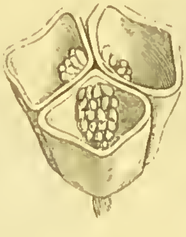


Fig. 960.

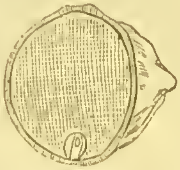


Fig. 957. Flowering plant of the Colchicum or Meadow Saffron (*Colchicum autumnale*).—*Fig.* 958. Diagram of the flower of the same, with six divisions to the perianth arranged in two whorls, six stamens, and a 3-celled ovary.—*Fig.* 959. Transverse section of the capsule.—*Fig.* 960. Vertical section of the seed.

3. *Asphodeleæ*.—In this tribe the stem is a rhizome; the leaves are either radical or borne upon an aerial simple stem.

4. *Allioideæ*.—Bulbous plants with umbellate inflorescence, generally enclosed in two or more spathaceous bracts. *Allium*, the Onion, has usually tubular leaves. The inflorescence frequently shows bulbils among the flowers.

5. *Dracæneæ.* — This tribe includes the genera *Yucca* and *Dracæna*, which are exceptional among the Monocotyledons in possessing an arborescent stem which increases in thickness by means of a peculiar cambium layer. The fruit in some genera is a berry.

6. *Asparageæ.*—In this tribe the stem is a rhizome which sends up leafy sub-aerial branches ; the fruit is a berry.

Asparagus bears aerial shoots which are very copiously branched. The apparent leaves, which occur crowded together in clusters, are really leafless shoots or cladodes, the true leaves, which are scaly, subtending clusters of them. *Ruscus aculeatus* bears leaflike phylloclades, from the centre of each of which the flowers are borne. The true leaves are scaly structures which subtend the phylloclades and which soon drop off. Its flowers are diclinous. *Paris quadrifolia* bears tetramerous solitary flowers ; it approaches the *Melantheæ* in having free styles. Its foliage leaves, usually four in number, are borne in a whorl below the flower. *Convallaria*, the Lily of the Valley, has its six perianth segments fused together to form a white cup, which appears as if it were a single whorl, the segments being displaced to the same level.

Fig. 961.

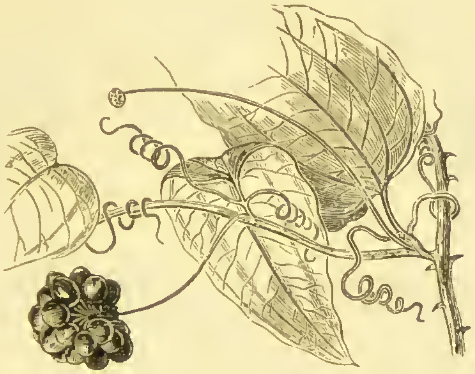


Fig. 961. Portion of a branch, with leaves and fruit, of *Smilax papyracea*.

7. *Smilaceæ.*—These are climbing plants with their stipules or leaf-sheaths modified into tendrils (*fig.* 961). The leaves have reticulate venation. The plants are diœcious, and the ovules orthotropous or amphitropous.

8. *Philesieæ.*—A small South American tribe with perigynous stamens, and a 1-celled ovary with parietal placentation. They approach the *Roxburghiaceæ* in many points.

Order 3. PONTEDERIACEÆ.—A small order of aquatic plants found in the tropics, especially tropical America. They differ from *Liliaceæ* chiefly in having zygomorphic flowers. There is frequently a reduction in the number of stamens, and in *Pontederia* the ovary has only one cell and contains a single ovule.

Order 4. PHILYDRACEÆ.—A small order of East Asian and Australian plants. They have a 3-leaved petaloid perianth, one stamen, and two petaloid staminodes. The ovary and fruit resemble those of *Liliaceæ*.

Order 5. XYRIDACEÆ.—Tropical marsh plants, somewhat resembling Sedges in their appearance. They differ from *Liliaceæ* in their scarious perianth, in having only a single whorl of stamens, and a unilocular ovary with parietal placentation. Their anthers are extrorse.

FIG. 962.

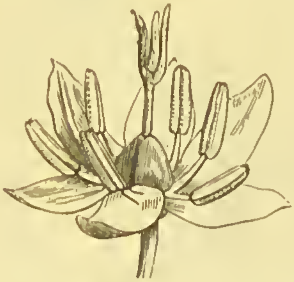


FIG. 963.

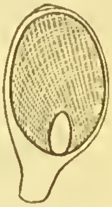


Fig. 862. Flower of a species of Wood-rush (*Luzula*), having an inferior perianth with six divisions, six stamens, and a superior ovary with one style and three stigmas.——*Fig.* 963. Vertical section of the seed of the same.

Order 6. COMMELYNACEÆ.—These plants have nodose stems, with flattened, often sheathing leaves. The perianth is 2-whorled, the outer being sepaloid. The stamens are typically six, but some are generally abortive; the filaments are sometimes clothed with coloured hairs (*Tradescantia*). The ovary is like that of the *Liliaceæ*.

Order 7. MAYACEÆ.—A small order of tropical American plants. They differ from *Commelynaceæ* in having 1-celled anthers and a 1-celled ovary with parietal placentation. They are somewhat moss-like in appearance.

Order 8. RAPATEACEÆ.—A small order of South American marsh plants with radical leaves. The main stem is crowned by a number of spikelets which have the appearance of a kind of capitulum.

Series 4.—*Calycinæ*.

The plants of this series have a sepaloid perianth, of which the inner whorl is small and very rarely slightly coloured. The ovary is superior, and the seeds contain considerable endosperm.

Order 1. FLAGELLARIEÆ.—This is a small order of tropical plants chiefly found in the Malay Archipelago, Asia, and Africa. It is often referred to *Juncaceæ*, from which it differs in the structure of the seed.

Order 2. JUNCACEÆ.—These plants differ from *Liliaceæ* only in the character of the perianth, which is scarious instead of being petaloid (*fig.* 962). In some cases the inner whorl of stamens is abortive, and in others the ovary is unilocular. The style is divided at the summit and bears three stigmas. The embryo shows no differentiation into members. The order approaches the Sedges and Grasses in the character of its sheathing glabrous foliage leaves, the sheath of which is open in some species, but closed in others; it has no ligule. The inflorescence is an anthela, which is often displaced laterally by its subtending leaf.

Juncus, the Rush, has usually cylindrical leaves with an open sheath; *Luzula* has flat leaves, the edges of whose sheath are united. The Rushes have usually stellate parenchyma in the centre of their leaves and stems.

FIG. 964.

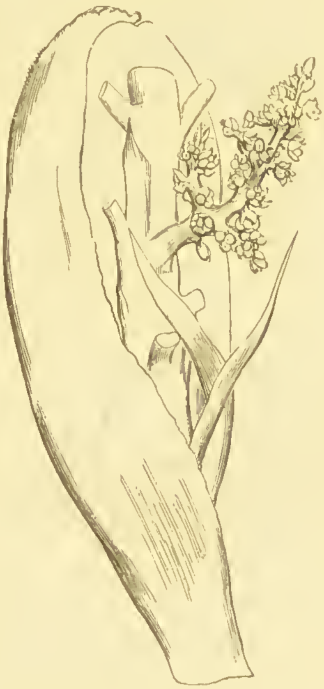


Fig. 964. Branched spadix of *Chamærops* enveloped in a spathe.

Order 3. PALMACEÆ.—The plants of this order have usually a very characteristic habit; they are for the most part trees whose stems are cylindrical and unbranched, and whose leaves are borne thickly together, the internodes remaining very short. The stem is then covered with leaf scars, or with the actual bases of the leaves which have perished. On the summit of the trunk there is usually a close-packed rosette of large leaves. In a few cases, particularly in *Calamus*, the internodes are long; the habit is then different, the plants creeping or climbing. In the Doum-palm (*Hyphæne*) the stem is branched. The palms have no persistent primary root, but develop a large number of adventitious fibrous roots. The leaves are very distinctive of the group; they have sheathing petioles of some dimensions, which terminate in large fan-shaped laminæ, the latter folded in the bud. The laminæ become torn or split during their development. In some cases a palm only bears one inflorescence and dies after flowering. The inflorescence is borne on a fleshy axis, which is often branched. This spadix may be enclosed in a single spathe, or there may be a spathe for each branch. The flowers are never stalked, and may be partially sunk in the tissue of the spadix. They are diclinous as a rule, sometimes monœcious, sometimes diœcious. The perianth is usually 2-seriate, sepaloid, persistent, and often fleshy. The staminate flowers usually possess six stamens, but the number is not constant; there may be three, or they may be numerous. The

FIG. 965.

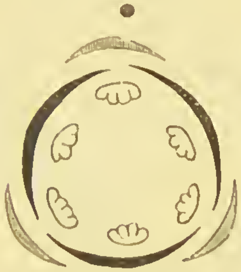


FIG. 967.

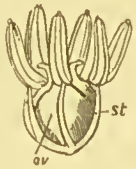


FIG. 968.

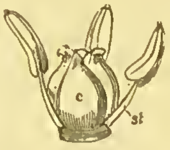


FIG. 966.

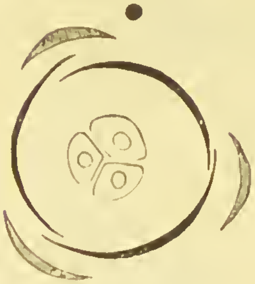


FIG. 969.

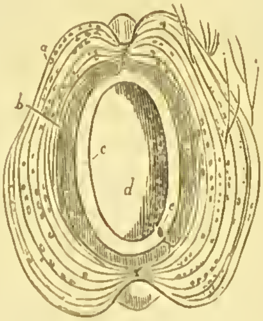


FIG. 970.

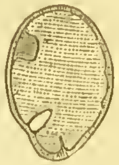


Fig. 965. Diagram of a staminate flower of the Fan Palm (*Chamærops*), with six divisions to the perianth, and six stamens.——*Fig.* 966. Diagram of a pistillate flower of the same, with six divisions to the perianth, and a 3-celled ovary.——*Fig.* 967. Hermaphrodite flower of the Blue Palmetto (*Chamærops hystrix*), with the perianth removed. *ov.* Carpels. *st.* Stamens.——*Fig.* 968. The same, with three of the stamens removed, so as to exhibit more completely the three carpels composing the pistil. *st.* Stamens. *c.* Carpels.——*Fig.* 969. Vertical section of the fruit of the Cocoa-nut Palm (*Cocos nucifera*). *a.* The two outer layers or husk of the pericarp. *b.* Endocarp or inner layer. *c.* Endosperm. *d.* Cavity in the endosperm. *e.* Embryo.——*Fig.* 970. Vertical section of the seed of the Fan Palm.

pistillate flowers have three carpels, sometimes free, sometimes combined to form a 1—3-celled ovary. Each carpel bears a single ovule, but two out of the three are usually abortive, together with the loculi in which they originate. The fruit is a berry, a drupe, or a nut, with, as a rule, a single seed which contains a considerable quantity of endosperm. The latter is very varied in composition: in the Date it is hard and horny; in the Cocoa-nut it is thin-walled and contains a quantity of oil; in the tribe *Sabaleæ* it is ruminated.

The order is divided into several tribes, but the divisions adopted by various authors are not uniform. The order is mainly tropical in its distribution.

Series 5.—*Nudifloræ.*

In this series the perianth is usually wanting, but it may be represented by setæ or scales. The ovary is superior; it may be either monocarpellary or syncarpous. The ovules may be 1—∞; the seeds generally contain endosperm.

Order 1. PANDANACEÆ.—This is a small order which shows resemblances on the one hand to the Palms, and on the other to the Aroids. The stems are arborescent and give rise to a number of adventitious roots; the leaves are arranged in crowns, and are long and narrow and often spiny. The flowers are diœcious, and are arranged on spadices, which become succulent and unite with the drupaceous or baccate fruits to form soroses. The order is found in the Malay Archipelago and Australia.

Order 2. CYCLANTHACEÆ.—This is a small order of tropical American plants, sometimes included in the *Pandanaceæ*. The flowers are diclinous, and are arranged in close spirals or in whorls on an unbranched spadix.

Order 3. TYPHACEÆ.—This is a small order of marsh plants with rhizomes which bear aerial shoots on which the leaves arise in two rows. The leaves are linear and greatly elongated. The flowers, which are diclinous, are borne on globose or cylindrical capitula, or spadices, which are often of considerable length. The staminate inflorescences are situated near the apex of the plant, and the pistillate ones lower down. There is a perianth, which consists of a number of scales or bristles; the staminate flower has three stamens, the pistillate flower has one or two carpels and bears only one ovule, which is pendulous.

Sparganium and *Typha* both occur in Britain. In the former the capitula are globose and the perianth is 3-leaved. In the latter the perianth is represented by a number of hairs, and the staminate flowers have monadelphous stamens.

Order 4. ARACEÆ.—These are plants of very varied habit and of very wide distribution. Some are climbers, attaching themselves by adventitious roots to trees or rocks; some are altogether epiphytic; some have a thick upright stem; many have only underground stems, which may be tubers or rhizomes.

FIG. 971.

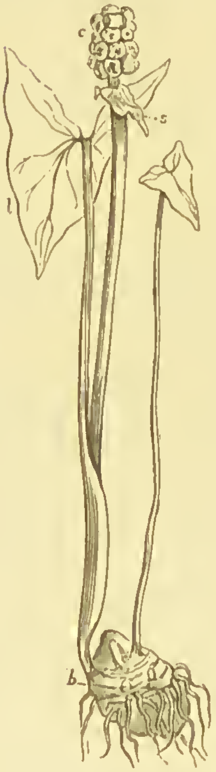


FIG. 972.

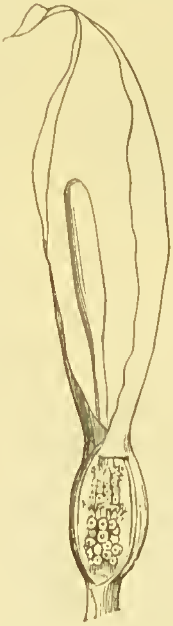


FIG. 973.

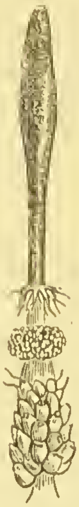


FIG. 974.

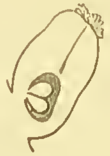


FIG. 975.

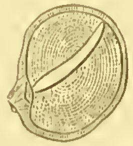


Fig. 971. A plant of the Cuckoo-pint (*Arum maculatum*) in fruit. *b.* Corm. *l.* Leaf. *s.* The remains of the spathe. *c.* Fruit.——*Fig.* 972. Inflorescence (spadix) of the same, with part of the spathe cut away to show the flowers.——*Fig.* 973. The spadix of the same with the spathe removed; the flowers are all naked, a number of pistillate flowers or ovaries are at the base, above them are some rudimentary ovaries, then a number of sessile anthers, and above these are some staminodes or abortive stamens.——*Fig.* 974. Vertical section of the ovary of the same.——*Fig.* 975. Vertical section of the seed.

The leaves are reticulately veined, and many are formed on the pinnate type. The cymose type is, however, often met with, many species having pedate leaves. Many of the pinnately veined forms are cordate or sagittate. In all cases they are glabrous. The inflorescence is a thick spadix, usually provided with a spathe, which in many species is large and brightly coloured. The flowers are generally diclinous, but in some species they are perfect. In the diclinous forms the pistillate flowers are arranged in a group, lower down than the staminate ones (*fig.* 973). In some species there is a ring of barren staminate flowers above the others. In some the stamens are free, in others monadelphous. In some pistillate flowers staminodes occur. In *Arisarum* the staminate flowers consist of a single stamen, and the pistillate ones of a solitary carpel. Some have a perianth, others have not; in those which have, the leaves may be free or coherent. The fruits are berries; the ovules may be orthotropous, anatropous, or campylotropous; there may or may not be endosperm in the seeds. They show a great variety also in their internal structure.

The order may conveniently be divided into three tribes as under:—

1. *Aroideæ.*—The flowers are monœcious and have no perianth, and are surrounded by a large spathe.

Arum maculatum, the Cuckoo-pint or Lords and Ladies, has a spadix which terminates in a naked club-shaped swelling; below this is a number of rudimentary staminate flowers which close a constriction in the folded spathe so as to form a kind of chamber in which the true flowers are situated, the pistillate ones being at the bottom of the spadix and the staminate ones just below the throat of the spathe (*figs.* 972, 973).

2. *Acoreæ.*—The flowers are perfect, and there is usually a perianth, which is 2-seriate; two whorls of stamens are generally present.

Acorus Calamus, the Sweet Flag, is common in the eastern counties of England. It has a triquetrous rhizome, which bears long ensiform leaves, which when bruised are fragrant. The inflorescence is terminal, but becomes apparently lateral, through a displacement caused by the spathe, which grows on in the line of the flowering stem. The spadix bears a dense aggregation of flowers.

3. *Calleæ.*—The flowers are perfect, but have no perianth. There are six to nine stamens and a 1-celled ovary.

Monstera deliciosa is cultivated in greenhouses as an ornamental plant. It has curiously perforated leaves, the apertures in which are caused by the growth of the vascular bundles being faster than that of the tissue between them, the latter being consequently torn.

The plants of this order are all more or less acrid, and often highly poisonous, but this acrid principle is frequently volatile, or decomposed by heat; hence it may be in some cases more or less destroyed by drying or exposing to heat the parts in which it is found. The best method of getting rid of the acridity is, however, that of boiling in water, as the acrid matter is commonly soluble in that fluid. Starch is usually associated with the acrid principle, and when extracted, may be used for food like other starches. The underground stems or corms of many species, when cooked, are eaten in different parts of the world. Some are aromatic stimulants; others expectorant, antispasmodic, or diaphoretic.

Order 5. LEMNACEÆ.—These are small free-swimming plants which occur on the surface of ponds or still streams. The plant body is a thallus from which roots hang downwards; the thallus branches cymosely. The inflorescence is a much reduced spadix consisting of two staminate flowers and a single pistillate one, borne on a branch of the thallus. Each staminate flower consists of a single stamen, and each pistillate one of a single carpel.

FIG. 976.

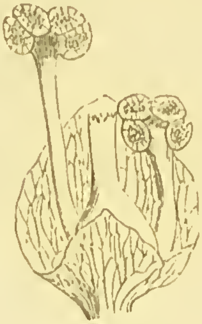


FIG. 977.

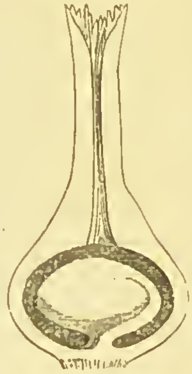


Fig. 976. A monœcious head of flowers of a species of Duckweed (*Lemna minor*), consisting of two male flowers, each of which is composed of a solitary stamen with a quadrilocular anther; and one pistillate flower in the centre; the whole surrounded by a spathe.——*Fig.* 977. Vertical section of the pistil of the same.

Lemna is the Duckweed. There are several species, most of which are common on stagnant water. They have a thin membranous urn-shaped spathe. *Wolffia arrhiza* is the smallest flowering plant known; it has no roots, no vascular tissue, and no spathe.

Series 6.—*Apocarpæ.*

These plants are characterised by having distinct or solitary carpels. The ovary is superior, the stamens hypogynous, and the seeds exalbuminous. The perianth is sometimes biseriate, sometimes uniseriate, sometimes absent.

Order 1. TRIURIDACEÆ.—This is a small order of tropical plants allied to *Naiadaceæ*, but usually to be distinguished from them by a rudimentary embryo. The flowers also are sometimes perfect.

Order 2. ALISMACEÆ.—The plants of this order are either aquatic in habit or grow in marshy places. They have radical leaves and long-stalked inflorescences. The flowers are regular and typically perfect, but in many the andrœcium or gynœcium is suppressed. The perianth is in two whorls, the inner of which is usually petaloid. There is often a greater number of stamens than is typical, the three of the outer whorl being chorised to form six, making nine in all, or several additional whorls of three each being intercalated between the normal whorls and the pistil. The carpels undergo a similar augmentation, and in some cases are arranged spirally. The carpels are distinct or partially coherent at their bases.

FIG. 978.

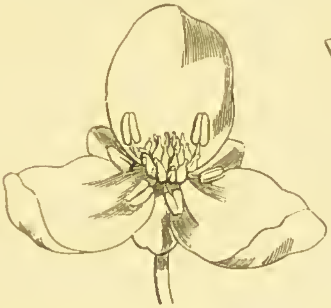


FIG. 979.

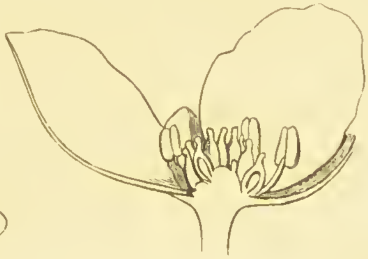


Fig. 978. Flower of a species of *Alisma*, with an inferior perianth arranged in two whorls, each consisting of three parts, six stamens, and numerous separate carpels.——*Fig.* 979. Vertical section of the same flower.

There are two principal tribes or divisions of the order.

1. *Alismeæ.*—The fruits in this division are achenes, and the embryo is curved.

Alisma has six stamens in the outer whorl, the inner whorl being suppressed. It has a large number of free carpels crowded together on a broad receptacle. *Sagittaria* has monœcious flowers, numerous stamens and carpels. The former are arranged in several whorls, the latter exhibit spiral phyllotaxis. The plant is heterophyllous, its submerged leaves being ribbon-shaped, and its sub-aerial ones sagittate or arrow-shaped.

Fig. 980.

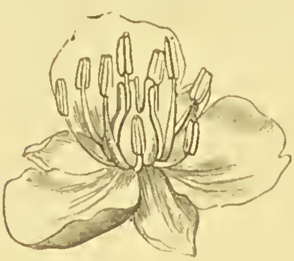


Fig. 981.

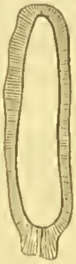


Fig. 980. A flower of the Flowering Rush (*Butomus umbellatus*), with an inferior perianth arranged in two whorls, nine stamens, and six carpels. *Fig.* 981. Vertical section of the seed of the same.

2. *Butomeæ.*—The fruits are follicles with many seeds, which are borne all over the inner surfaces of the carpellary leaves. The embryo is not curved.

Butomus umbellatus has an umbellate inflorescence, which is really composed of three helicoid cymes. The outer whorl of stamens is doubled and the inner whorl is present, and there are two whorls of three carpels The plant springs from an underground rhizome.

Order 3. NAIADACEÆ.—The plants of this order, like those of the last, have either an aquatic or marshy habitat. The perianth may be absent, or may have two, four, or six segments; in the last two cases they are in two series. They are usually sepaloid and inconspicuous. The flowers are sometimes diclinous; the stamens may be one to four or six, in two whorls. The carpels are generally free, one to six in number; sometimes two whorls of three each are present; sometimes the outer whorl of these is abortive.

The order is divided into the following tribes:—

1. *Juncagineæ.*—These plants are sometimes diœcious; the perianth has two sepaloid whorls, two whorls of stamens with extrorse anthers, and two whorls of carpels, of which one is sometimes suppressed; in some species the carpels are coherent together.

Triglochin has its flowers arranged in long lax spikes without bracts. The pistil is bicarpellary and syncarpous; the fruit is a schizocarp, splitting from below upwards.

2. *Aponogetoneæ.*—Aquatic plants with a tuberous stem. The perianth is single and petaloid; as a rule there are six stamens and three carpels.

Ouvirandra fenestralis is cultivated in greenhouses. It has peculiar latticed leaves, the mesophyll between the veins becoming absorbed as the leaf grows.

3. *Potameæ.*—The perianth is absent; the flowers are dimerous and perfect. The fruits are nuts or drupes; the embryo is curved.

The plants are generally quite submerged, but a few species have floating leaves.

Potamogeton has a creeping sympodial rhizome, and its flowers are borne in spikes. The flowers have four stamens, with a broad leafy connective, simulating a perianth ; there are four free carpels. *Ruppia* has only two stamens.

4. *Posidonieæ.*—These are marine plants bearing diclinous flowers with no perianth ; the staminate flower consists of three stamens, the pistillate one of a solitary carpel.

5. *Zannichellieæ.*—The flowers are monœcious, or sometimes diœcious. In *Zannichellia* the staminate flower has one stamen and is naked ; the pistillate flower has a bell-shaped perianth surrounding four to six carpels.

6. *Zostereæ.*—These are marine plants growing in brackish water. They are either monœcious or diœcious.

Zostera, the Grass-wrack, is an entirely submerged plant with ribbon-like leaves. It bears a curiously flattened spike, on one side of which are two rows of flowers. The perianth is not developed, and there is a solitary stamen and a solitary carpel. The pollen is linear.

7. *Naiadeæ.*—These are annual herbs living in fresh water. The flowers are diœcious ; the staminate flower consists of a single stamen, with sometimes four pollen sacs and sometimes only one. The anther is an axial structure, being developed at the apex of the axis, which it terminates. It is surrounded by a ring-like outgrowth, which probably represents a perianth that originates late in the course of the floral development. There is also an outer sac or envelope to the anther, which may be homologous with the spathe of some allied forms and with the cup-shaped envelope of Zannichellia. The ovule is also terminal ; as it develops, a ring-like wall grows up round it, the margin of which becomes 2—3-lobed ; this structure ultimately forms a closed chamber with the ovule inside. It is not to be confused with the integuments of the latter, which are developed normally. Nor can it be considered a carpel, from the order of the development. It may be homologous with the perianth of *Zannichellia*, which surrounds several carpels, the latter being here reduced to one and the ovary being suppressed, the ovule alone being developed.

8. *Cymodoceæ.*—Marine plants with diœcious flowers. There is no perianth ; the staminate flowers have two connate stamens, the pistillate ones two carpels ; there is a single orthotropous ovule.

Series 7.—*Glumaceæ.*

The plants of this series have their flowers arranged in spikelets or heads ; they are invested by membranous bracts or glumes, which are often imbricated and always sessile; the perianth is very much reduced, and is never represented by any but scale leaves; it may be entirely absent. The ovary is superior, uni- or multilocular; each loculus contains a single ovule. The seeds have endosperm.

Order 1. ERIOCAULACEÆ.—A tropical order of aquatic or marsh-loving plants, whose flowers are arranged in capitula surrounded by involucra. The flowers are small and diclinous; the same capitulum usually contains both staminate and pistillate flowers. The perianth is 2-seriate, and its leaves are membranous; the stamens are in two whorls of three; there are three carpels, which form a 2—3-celled capsule in fruit.

FIG. 982.

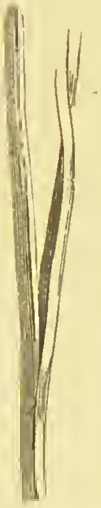


FIG. 983.

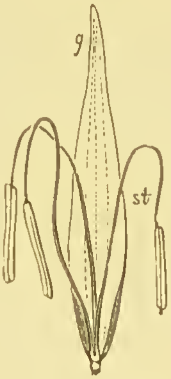


FIG. 984.

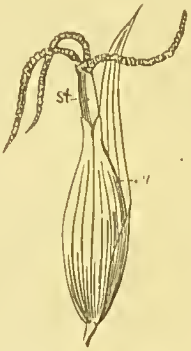


Fig. 982. A portion of the angular stem of a species of *Carex*, with a closed leaf-sheath.——*Fig.* 983. Staminate flower of a species of *Carex*. *st.* Stamens, with long filaments and pendulous innate anthers. *g.* Glume.——*Fig.* 984. Pistillate flower of a species of *Carex*, consisting of a glume at the base, and a pistil surrounded by an urn-shaped tube (*perigynium*), *u.* *st.* Style, terminated by three stigmas.

Order 2. CENTROLEPIDEÆ.—A small order of plants, mainly Australian. They are allied to *Eriocaulaceæ* by the structure of their fruit and seed. They show affinities also to *Restiaceæ*, with which they were formerly included. They differ from both these orders in having no perianth. This order has also been called *Desvauxiaceæ*.

Order 3. RESTIACEÆ.—A small order chiefly occurring in South Africa and Australia. The plants have a xerophytic habit, resembling that of the Rushes and Sedges. The leaves are simple and narrow, or reduced to their sheathing petioles. The flowers are diœcious;

the perianth is biseriate and scarious; the stamens are three and are antipetalous. The ovary is 1—3-celled.

Order 4. CYPERACEÆ.—The plants of this order are perennial or rarely annual herbs with a sympodial rhizome, from which sub-aerial stems are sent up. The latter are usually solid and triangular, and do not show the swollen nodes characteristic of Grasses. The leaves are arranged in rows along each side of the triangular stem, so that they are in three ranks. The petioles are sheathing, but the sheath is closed in front. The ligule of the Grasses is seldom represented, and is then very insignificant. The flowers are arranged in spikes or spikelets, and these are gathered into compound spikes or racemes. The flowers arise in the axils of bracts which are membranous. They are diclinous in some genera, perfect in others. The perianth of the typical monocotyledonous flower is generally altogether wanting, but its place is sometimes taken by six bristles (*fig.* 985) or by a number of hairs. The flower has three stamens, which represent the outer or antisepalous whorl; the anthers are innate. The pistil is typically trimerous, but sometimes there are only two carpels; there is a single style, branched at the apex and bearing two or three stigmas; the ovary is 1-celled, and bears a single erect anatropous ovule. The fruit is a kind of nut.

FIG. 985.

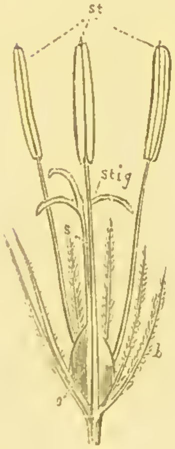


FIG. 986.

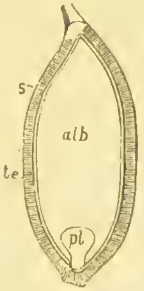


FIG. 987.

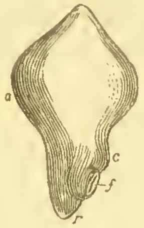


Fig. 985. Flower of a species of Club-rush (*Scirpus*)’ the glume having been removed. *b.* Hypogynous setæ or bristles forming a kind of perianth. *st.* Hypogynous stamens with 2-celled innate anthers. *o.* Ovary. *s.* Style. *stig.* Stigmas.——*Fig.* 986. Vertical section of the fruit of a species of *Carex.* *s.* Pericarp. *te.* Integuments of the seed. *alb.* Albumen. *pl.* Embryo.——*Fig.* 987. Embryo of a species of *Carex* removed from the albumen. *a.* Lateral swelling. *r.* Radicle. *c.* Cotyledon. *f.* Slit corresponding to the plumule.

The order is divided into two tribes, as under:—

1. *Scirpeæ.*—The flowers in this tribe are perfect; the bracts are arranged either spirally or in two rows. Flowers are sometimes absent from the axils of the lower ones. The spikelets are composed of several flowers; the perianth is absent or composed of bristles. In *Eriophorum* these are developed into a bunch of woolly hairs.

2. *Cariceæ.*—The flowers are diclinous; the bracts are in many rows. The staminate and pistillate flowers are sometimes in the same spikelet, but generally this is not the case, a spikelet being either staminate or pistillate.

Carex is the most representative genus of this tribe. It has naked, generally monœcious flowers. Each staminate flower consists of three stamens in the axil of a bract. The pistillate flower usually has three carpels; it is borne on a very small branch arising in the axil of a bract. Another bract is placed on this branch opposite to the first one, and the pistillate flower arises in its axil. As the flower develops, this bract grows and envelops it, forming a kind of cup- or urn-shaped body, known as a *perigone.*

Order 5. GRAMINEÆ.—The plants of this order, known as *Grasses*, are commonly annual or perennial herbs with hollow jointed stems and leaves with sheathing petioles, the sheath of which, with a few exceptions, is split; at the junction of the petiole and blade there is a ligule. There are exceptions, however, to this general character. Some tropical species, particularly the Bamboos, have an arborescent habit and bear tufted branches, especially from the axils of the basal leaves. Some species—*e.g.* Maize, Sugar-cane—have a solid stem. The leaf-blades are usually linear and flat, but many Grasses of xerophytic habit have the blades rolled up and consequently appearing almost cylindrical. The sheath is not split in a few species of *Melica*, *Poa*, *Bromus*, and *Glyceria.* The flowers are arranged in locustæ or spikelets, which may consist of a single flower, or of several, with usually a rudimentary one at the apex (*figs.* 988, 989). The flowers are usually in two alternate rows on the rachis of the spikelet. The spikelets themselves are variously grouped, so that the inflorescence may be a compound spike or a panicle. Each spikelet has a pair of membranous leaves at its base; these are known as *glumes* (*fig.* 989, *gl*). Sometimes there are more than two of these. On the axis of the spikelet, immediately above the inner glume, the first flower is placed. It has exteriorly two more scarious leaves, the lower of which resembles the glumes, while the upper one, opposite to the lower, has two nerves or midribs. The lower is usually called the *flowering* *glume*, or the *lower pale*; the binerved one is called the *upper pale*, or sometimes simply the *pale*. Inside the pales are generally

FIG. 988.

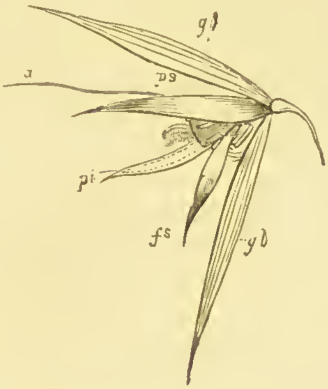


FIG. 989.

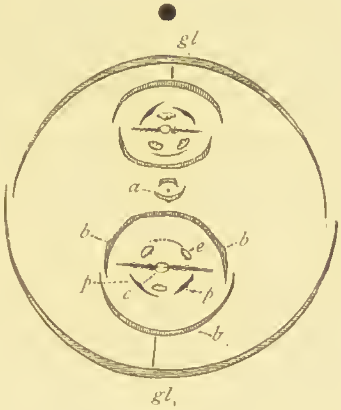


FIG. 990.

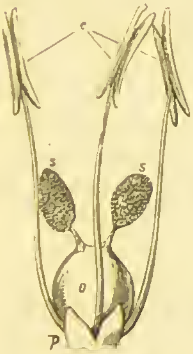


FIG. 991.

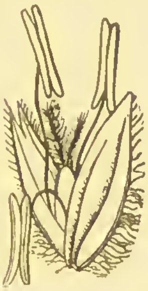


FIG. 992.

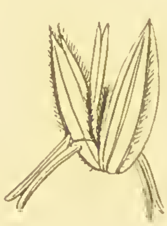


FIG. 993.

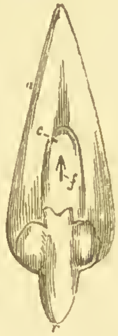


Fig. 988. Locusta or spikelet of the Oat (*Avena*). *gl.* Glumes. *ps*, *pi*. Pales. *a.* Awn arising from the back of the lower pale, *ps*. *fs*. An abortive flower.——*Fig.* 989. Diagram of a spikelet of the Oat (*Avena*). (From Le Maout.) *gl*, *gl*. Two glumes, enclosing two perfect flowers, and one, *a*, abortive. *b*. The outer palea or flowering glume. *b*, *b*. The inner palea. *p*, *p*. Two scales or **lodicules**; the dotted curved line above the stamens marks the position of a third abortive scale. *e*. Stamens. *c*. Ovary.——*Fig.* 990. Fertile flower of the Oat, without the paleæ. *p*. Lodicules. *e*. Stamens. *o*. Ovary. *s*, *s*. Feathery stigmas.——*Fig.* 991. One of the florets of a species of Meadow Grass (*Poa pratensis*).——*Fig.* 992. One of the florets of the Hard Fescue Grass (*Festuca duriuscula*).——*Fig.* 993. The embryo of the Oat. *a*. Scutellum. *c*. Cotyledon. *r*. Radicle. *f*. Slit from which the plumule will emerge.

two small scales, which are placed where the edges of the two pales overlap. These are known as the lodicules (*figs.* 989, *pp*, and 990, *p*). Sometimes a third is present, when it lies between the two nerves of the upper pale. In some species the lodicules are abortive. The stamens are usually three, the typical inner whorl of the monocotyledonous flower being absent. In some species all six stamens are present, and in others there are as many as eighteen stamens. When the flower opens, these stamens are exserted and the anthers are versatile ; they are of curious shape, being notched or indented at their ends. The pistil has only one carpel, but this may bear two or three styles, the former being the usual number. The style is much branched, and ends in two or three feathery or plumose stigmas. The ovary is 1-celled, and contains a single ovule. The fruit is a caryopsis, the pericarp being adherent to the testa of the seed. In some genera, particularly the Barley and Oat, the pales also become adherent to the fruit.

The glumes and the lower pales frequently bear a bristle-like body, known as an *awn*. This generally springs from the back of the leaf, a little behind the apex. Some morphologists consider this to represent the blade of the leaf, and the glume or pale to be only the sheathing base.

The structure of the Grass flower has been the subject of much controversy. Some morphologists suggest that it agrees fairly closely with the Liliaceous type, showing only a moderate degree of suppression of parts, together with the assumption of scarious instead of petaloid perianth leaves. The resemblance is traceable through the order Juncaceæ, in which the Liliaceous type is seen with membranous perianth. On this view the outer or sepaline whorl is represented by the lower and upper pales, the latter of which represents two of the sepals that have become gamosepalous. This is supported by the fact that this pale has two midribs, and is often cleft to various depths between them. In a species of *Bromus* this cleft extends to the base, so that there is a whorl of three leaves. The position of the midribs in the flower, situated as they are at an angular distance of 120°, supports this view. The corolla is represented by the lodicules, which occur in proper alternation with these midribs. If only two of these are present, they still occupy a position which is consistent with this view, the one which is suppressed leaving a space vacant between the two midribs of the upper pale. The andrœcium usually shows the suppression of the inner whorl, the three stamens which are present alternating with the lodicules. Suppression is seen in the pistil, but the original or typical three carpels are often suggested by three stigmas.

Other botanists do not accept this view, but consider the flower to have undergone reduction in a way similar to that which has affected many other Monocotyledons, particularly the Aroids and the members of the last series. They suggest the following explanation. The outer pale is the bract of the flower, and bears a floral shoot in its axil. The upper pale is a bracteole higher up on the shoot, and is binerved owing to pressure against the main axis during development. The lodicules represent a rudimentary perianth reduced to a single whorl, the outer whorl of the Juncaceæ having been entirely suppressed, and in most cases the posterior leaf of the inner whorl as well. The outer whorl of stamens on this view is the whorl which is suppressed.

A third view is that the lodicules also are bracteoles, the two antero-lateral lodicules representing the two halves of a single bracteole, which is present as such in *Melica*. On this hypothesis the flower is altogether naked, and its affinities are more closely with the Naiadaceous type.

The flowers of the Grasses are usually pollinated by the wind. Cleistogamic flowers occur in a few genera. When the flowers are mature they are caused to open by the lodicules, which expand and force the pales apart. The filaments then elongate very rapidly, and the anthers droop over the side of the spikelets. Self-pollination is very common, as the pollen is scattered over the open spikelet.

The order is usually divided into eleven tribes, as under :—

1. *Bambuseæ.*—Arborescent much-branched stems. Stamens six.
2. *Oryzeæ.*—Laterally compressed spikelets, two to four glumes; stamens six.
3. *Maydeæ.*—The flowers are diclinous and monœcious.
4. *Andropogoneæ.*—Tall grasses with solid stems; flowers monœcious or polygamous; glumes three.
5. *Festuceæ.*—Spikelets many-flowered; glumes shorter than the lower pales, which have no awn or a terminal one.
6. *Aveneæ.*—Spikelets usually of two flowers, sometimes with a rudimentary third one; glumes long, enclosing the spikelet; lower pale with a long twisted awn.
7. *Agrostideæ.*—Spikelets 1-flowered, arranged in panicles. Generally only one pale to each flower.
8. *Phalarideæ.*—Spikelets in panicles; each 1-flowered, with sometimes one or two rudimentary or staminate ones; glumes four, the inner pair being the smaller.
9. *Chlorideæ.*—Spikelets arranged in two rows on one side of a laterally compressed axis; each 1-flowered.
10. *Paniceæ.*—Spikelets dorsally compressed in compound spikes. Glumes three, the lowest smallest.
11. *Hordeæ.*—Spikes compound; spikelets sessile in the notches of a toothed rachis.

Artificial Analysis of the Orders in the Class.

MONOCOTYLEDONES.

(Modified from Lindley.)

Sub-Class I.—PETALOIDEÆ.

1. FLOWERS WITH AN EVIDENT PERIANTH.

A. Ovary inferior (*Inferæ* or *Epigynæ*).

a. *Flowers gynandrous.*	
Ovary 1-celled. Placentas parietal . . .	*Orchidaceæ.*
Ovary 3-celled. Placentas axile . . .	*Orchidaceæ* (*Apostasieæ*).
b. *Flowers not gynandrous.*	
1. Veins of leaves diverging from the midrib, and parallel to each other.	
Embryo enclosed in endosperm.	
Anther 2-celled. Filament 1, not petaloid	*Scitaminaceæ* (*Zingibereæ*).
Embryo not enclosed in endosperm.	
Anther 1-celled. Filament 1 . .	*Scitaminaceæ* (*Maranteæ*).
Anther 2-celled. Filaments more than 1	*Scitaminaceæ* (*Museæ*).
2. Veins of leaves diverging from the base, and parallel to the midrib.	
Stamens 3.	
Anthers extrorse	*Iridaceæ.*
Anthers introrse	*Burmanniaceæ.*
Stamens 6.	
Anthers extrorse	*Burmanniaceæ.*
Anthers introrse.	
Leaves equitant	*Hæmodoraceæ.*
Leaves flat.	
Fruit 1-celled	*Taccaceæ.*
Fruit 3-celled.	
Outer whorl of the perianth petaloid	*Amaryllidaceæ.*
Outer whorl of the perianth not petaloid	*Bromeliaceæ.*
Stamens more than 6	*Hydrocharidaceæ.*
3. Veins of leaves reticulated.	
Flowers unisexual	*Dioscoreaceæ.*

B. Ovary superior (*Superæ*). Leaves parallel-veined.

a. *Outer whorl of the perianth herbaceous or glumaceous.*

Carpels more or less distinct.	
Seeds attached over the whole inner walls of the fruit	*Alismaceæ* (*Butomeæ*).
Seeds attached to axile or basal placentas.	
Flowers conspicuous. Embryo curved, without a slit	*Alismaceæ* (*Alismeæ*).
Flowers inconspicuous. Embryo straight, with a lateral slit	*Naiadaceæ* (*Juncagineæ*).
Carpels combined.	
Inner whorl of the perianth different from the outer.	
Placentas axile. Anthers 2-celled. Capsule 2—3-celled	*Commelynaceæ*.
Placentas parietal.	
Anthers 2-celled. Capsule 1-celled	*Xyridaceæ*.
Anthers 1-celled. Capsule 1-celled	*Mayaceæ*.
The outer and inner whorls of the perianth alike.	
Flowers on a spadix. Embryo with a lateral slit	*Araceæ*.
Flowers not on a spadix. Embryo without a slit	*Junceaceæ*.

b. *Outer whorl of the perianth petaloid, or the whole petaloid when only one whorl is present.*

Carpels more or less distinct.	
Seeds solitary. Flowers on a spadix	*Palmaceæ*.
Seeds numerous. Flowers not on a spadix.	
Anthers extrorse	*Liliaceæ* (*Melantheæ*).
Anthers introrse.	
Perianth of 6 parts. Seeds without albumen	*Alismaceæ* (*Butomeæ*).
Perianth of 2 parts. Seeds with albumen	*Philydraceæ*.
Carpels combined.	
Flowers on a spadix	*Palmaceæ*.
Flowers not on a spadix.	
Perianth rolled inwards after flowering. Aquatics	*Pontederiaceæ*.
Perianth not rolled inwards after flowering, conspicuous	*Liliaceæ*.

C. Ovary superior. Leaves net-veined.
a. *Placentas basal* . . . . *Roxburghiaceæ.*
b. *Placentas axile* . . . . . . *Liliaceæ (Smilaceæ).*
c. *Placentas parietal* . . . . . *Liliaceæ (Philesieæ).*

2. FLOWERS EITHER NAKED, OR WITH A WHORLED SCALY PERIANTH, GENERALLY UNISEXUAL.

A. Flowers on a spadix.
a. *Flowers bisexual.*
Embryo cleft . . . . *Araceæ.*
Embryo solid . . . . *Pandanaceæ.*
b. *Flowers unisexual.*
Embryo solid . . . . *Pandanaceæ.*
Embryo cleft on one side.
Flowers with a true spathe. Fruit succulent.
Anthers sessile, or nearly so . . . . *Araceæ.*
Flowers without a true spathe. Fruit dry.
Anthers on long filaments . . . . *Typhaceæ.*

B. Flowers not arranged on an evident spadix.
a. *Flowers bisexual.*
Ovary superior . . . . . . *Naiadaceæ (Juncagineæ).*
Ovary inferior . . . . *Hydrocharidaceæ.*
b. *Flowers unisexual.*
Ovules erect.
Embryo perfect.
Seed without albumen . . . . . *Naiadaceæ.*
Embryo rudimentary . . . . . *Triuridaceæ.*
Ovules pendulous.
Carpel solitary.
Seed without albumen.
Pollen globose or tubular . . . *Naiadaceæ.*
Seed with albumen . . . . . *Restiaceæ.*
Carpels several, distinct.
Anthers 2-celled . . . . . . *Naiadaceæ.*
Anthers 1-celled . . . . . . *Centrolepideæ.*
Carpels several, combined.
Anthers 1-celled.
Stamens 2—3 . . . . . . *Restiaceæ.*
Stamen 1 . . . . *Centrolepideæ.*
Anthers 2-celled. Placentas axile.
Seeds with rows of hairs . . . *Eriocaulaceæ.*
Seeds without rows of hairs . . . *Restiaceæ.*
Anthers 2-celled. Placentas parietal . *Xyridaceæ.*

Sub-Class II.—GLUMACEÆ.

Stem solid. Leaf-sheaths not slit. Embryo basilar, within the albumen . . . . . *Cyperaceæ.*
Stem hollow. Leaf-sheaths slit. Embryo basilar, outside the albumen . . . . . . *Gramineæ.*

Synopsis of the British Natural Orders of Class X.

MONOCOTYLEDONES.

A. Leaves net-veined.
  1. Floral envelopes whorled.
    Perianth inferior. Flowers perfect . { *Liliaceæ (Trilliaceæ).*
    Perianth superior. Flowers diœcious . *Dioscoreaceæ.*
  2. Perianth absent. Flowers on a spadix (monœcious) . . . . *Araceæ (Aroideæ).*

B. Leaves parallel-veined, persistent.
  1. Floral envelopes whorled or absent.
    a. Ovaries more than 1, with styles or stigmas distinct.
      Perianth 4-parted or 0, or inconspicuous { *Naiadaceæ (Potamogetoneæ).*
      Perianth 6-parted.
        Placentation diffuse . . . { *Alismaceæ (Butomeæ).*
        Placentation axile or basal.
          Flowers conspicuous . . . { *Alismaceæ (Alismeæ).*
          Flowers inconspicuous . . { *Naiadaceæ (Juncagineæ).*
    b. Ovary single.
      Ovary inferior.
        Stamen 1. Flowers gynandrous . . *Orchidaceæ.*
        Stamens free from the style.
          Perianth petaloid.
            Stamens 3, anthers extrorse . . *Iridaceæ.*
            Stamens 6, anthers introrse . . *Amaryllidaceæ.*
          Three outer segments of perianth herbaceous . . . . . . *Hydrocharidaceæ.*
      Ovary superior.
        Perianth hexapetaloid. Flowers perfect.
          Perianth conspicuous . . . . *Liliaceæ.*
          Perianth scale-like . . . . *Araceæ (Acoreæ).*
        Perianth more or less glumaceous, or partly coloured, or wanting.
          Flowers perfect. Perianth 6-parted, stamens 6 . . . . . . *Juncaceæ.*

Flowers monœcious.
Flowers on a spadix.
Spadix thick. Spathe absent . *Typhaceæ.*
Spathe present . *Araceæ (Aroideæ).*
Flowers not on a spadix.
Flowers capitate. Stamens 2—5 . *Eriocaulaceæ.*
Flowers 2 in a spathe, 1 ♂, 1 ♀ . *Lemnaceæ.*
Flowers in two rows on one side of the spathe, enclosed by a fold of the leaf, or solitary . . . . *Naiadaceæ.*

2. Floral envelopes imbricated, bract-like.
Leaves with entire sheaths, stems solid . *Cyperaceæ.*
Leaves with split sheaths, stems hollow *Gramineæ.*

CLASS XI.—DICOTYLEDONES.

The classification of this group has been made as follows by Bentham and Hooker.

Sub-Class I.—MONOCHLAMYDEÆ.

The flowers have never more than a single whorl of perianth leaves, which may be sepaloid or petaloid. Very frequently there is no perianth. The flowers in many cases are either pistillate or staminate. From their condition in these respects the sub-class has been called *Incompletæ*, or *Apetalæ*.

The group has been divided by Bentham and Hooker into eight series, each of which includes only a small number of Natural Orders. Unlike the series of the other sub-classes, these have not been divided into Cohorts.

Another method of classification of the group will be found on page 25.

Series 1.—*Curvembryeæ*.

The plants of this division possess an embryo, which is in nearly all cases curved, eccentric, lateral, or peripheral, but in a few instances is straight. It lies as a rule in a farinaceous endosperm. The flowers have usually both stamens and pistil, but in some genera are diclinous or polygamous. Petals occur in very few species; the stamens are generally equal in number to the segments of the perianth, and the ovary in most cases contains a single ovule in each loculus; frequently only one loculus is present.

Order 1. NYCTAGINEÆ.—The plants of this order are trees, shrubs, or herbs, whose stems are swollen at the nodes and bear simple exstipulate leaves, which are either opposite or arranged spirally. The prominent feature of them all is the perianth, which is single, regular, gamophyllous, and often petaloid; its lower part in most cases persists after flowering, and embraces the fruit as a false pericarp, becoming either succulent or woody. The stamens vary in number from one to thirty; the pistil is monocarpellate, and contains a single ovule. The flowers have an involucre or epicalyx.

These plants are remarkable for the presence of a purgative property in their roots; which is especially the case with those of *Mirabilis Jalapa* and *M. longiflora*. *M. dichotoma*, Marvel of Peru, is commonly known by the name of the Four-o'clock Plant, from opening its flowers in the afternoon. *Boerhaavia diffusa* is said to possess expectorant properties.

Order 2. ILLECEBRACEÆ.—This is a small order which is now by many botanists considered only a section of *Caryophyllaceæ*, and will be described with that order, of which it forms the tribe *Paronycheæ*.

Order 3. CHENOPODIACEÆ.—These are nearly all herbaceous plants which show considerable affinity to the *Caryophyllaceæ*, but except in the genus *Salicornia* they have not opposite leaves. A considerable number of the species are fleshy or succulent. The stems and leaves of many are 'mealy,' an appearance which is due to the character of the hairs which they bear. A great many others are glabrous. The flowers are small, and are gathered into dense panicles which are without bracteoles. In some cases they are diclinous. There is a single whorl of perianth leaves, which are sepaloid; a single whorl of stamens, which are opposite to the perianth segments; and a 2—5-carpellate unicellular ovule with a single ovule. The fruit is usually a utricle or nut.

The position of the stamens opposite to the segments of the perianth is thought by many botanists to be due to both whorls being essentially spiral in their arrangement. The turns of the spire bring the members opposite to each other. On this hypothesis, we have not here a suppression of a corolla.

The order includes the following tribes:—

1. *Chenopodieæ*, with a regular 5-parted perianth, and both stamens and pistil in the flowers. All the genera have hypogynous flowers except *Beta* (the Beet).
2. *Salsoleæ*, with fleshy, almost cylindrical leaves.
3. *Salicornieæ*, with succulent jointed stems and inconspicuous opposite leaves. The seeds have no endosperm.
4. *Atripliceæ*, with generally diclinous flowers.
5. *Baselleæ*, which have a climbing habit. The flowers have two rows of coloured sepals, and perigynous stamens.

Order 4. AMARANTACEÆ.—The plants of this order are very much like those of the *Chenopodiaceæ*, and resemble also certain of the *Caryophyllaceæ*. The chief differences between them and the last order are that the perianth leaves are dry and membranous, and the flowers have two large bracteoles, which are in many cases coloured, but may be like the perianth. All these dry leaves are persistent.

Amarantus spinosus and other Indian species contain a good deal of mucilage. *Achyranthes aspera* is reputed to be also astringent and diuretic. *Gomphrena officinalis* and *G. macrocephala* are used in Brazil in intermittent fevers, diarrhœa, and some other diseases. Some of the species have bright-coloured persistent flowers, and are hence cultivated in our gardens, as *Amarantus caudatus*, Love-lies-bleeding; *Amarantus hypochondriacus*, Prince's-feathers; *Celosia cristata*, Cockscomb, with its fasciated inflorescence; and others.

Order 5. PHYTOLACCACEÆ.—This order includes a number of herbs or undershrubs with scattered simple exstipulate leaves. The flowers have a perianth which in many cases is petaloid, and many of them exhibit two whorls of stamens. Sometimes only one whorl is present. The stamens of one or of both whorls undergo chorisis in many species, so that there may be ten, fifteen, twenty, or twenty-five stamens. The number of carpels also varies; when there are many the ovary is syncarpous and many-celled, each cell bearing a solitary ovule. The styles in these cases are free. The fruit varies, being in some cases a berry, in others a nut, capsule, or schizocarp.

Order 6. BATIDACEÆ.—This order only includes one plant, *Batis maritima*, a succulent shrubby species found in the West Indies. It has opposite leaves, and diclinous flowers arranged in catkins.

Order 7. POLYGONACEÆ.—The plants of this order are herbs or rarely shrubs. They have alternate leaves, arranged upon rounded stems with swollen nodes. The leaves bear stipules, and have further a sheathing base. This base is united with the stipules to form a peculiar sheathing tubular structure, known as an *ochrea*. The flowers are usually regular, and have a perianth of from five to six segments, which in some flowers is arranged in one whorl, and in others in two. The stamens are in some cases in a single whorl, and in others in two; the number is very variable, but generally lies between five and nine. The gynœcium has two to three carpels, and is 1-celled. There is a single orthotropous ovule, borne upon the summit of the thalamus, which protrudes into the ovary, and is surrounded by the walls of the carpels. The growing point of the thalamus gives rise to the ovule, which is therefore axial, much as it is in the Yew tree, and is not borne upon the carpels. The styles are free, and correspond in number to the carpels. The fruit is a triangular nut, which is more or less enveloped by the persistent perianth.

The flowers of this order are remarkable for their extreme variability, which is seen especially in the genus *Polygonum*. In *Pterostegia* they are regular, with five whorls of three members each; *Rheum* differs in having the external staminal whorl doubled. *Rumex* has six stamens, but they are all in one whorl, which corresponds to the outer whorl of Rheum. *Polygonum* is pentamerous, but the number of stamens is not constant.

FIG. 994.

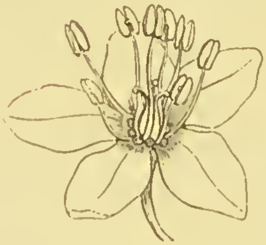
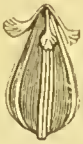


Fig. 994. Flower of a species of *Polygonum*. — *Fig.* 995. Pistil of a species of *Rumex*.

FIG. 995.



These plants are chiefly remarkable for the presence of acid, astringent, or purgative properties. The acid character is principally due to the presence of salts of oxalic acid. The fruits and roots of several species are more or less nutritious.

Series 2.—*Multiovulatæ aquaticæ.*

The plants of this series are submerged aquatic herbs. They have a syncarpous ovary, with numerous ovules in each loculus or on each placenta.

Order 1. PODOSTEMACEÆ.—The order comprises a number of aquatic plants of very varied appearance, which superficially resemble Mosses or Liverworts. The stem is in some dorsiventral, in others thalloid; the roots develop peculiar organs of attachment, by which the plants are anchored to rocks. The flowers are very minute, and are enclosed in a spathaceous bract; the stamens are one or many, hypogynous, sometimes monadelphous. The ovary is superior, 1—3-celled. The seeds are numerous, exalbuminous, and have a straight embryo.

Series 3.—*Multiovulatæ terrestres.*

These are arborescent plants with syncarpous ovaries, having numerous ovules in each loculus or on each placenta.

Order 1. NEPENTHACEÆ.—A small order of plants chiefly confined to tropical Eastern Asia. They are nearly all climbing shrubs with somewhat amplexicaul leaf-bases. The leaves are modified considerably; the petiole is the organ by which the plant climbs; it is winged for some distance from the base, and then becomes a tendril, and ends in a pitcher furnished with a lid. The wall of the pitcher contains certain glands which secrete a watery liquid, and this, under appropriate conditions, becomes a true digestive fluid, containing a proteolytic enzyme. Flies and other insects are entrapped into the pitcher, drowned, and digested, the products being absorbed by the wall of the pitcher. Most of the plants are epiphytic in habit.

FIG. 996.

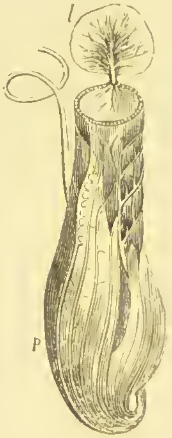


FIG. 997.

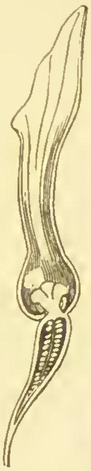
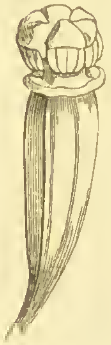


FIG. 998



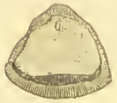


FIG. 999.

Fig. 996. Pitcher of Nepenthes. *Fig.* 997. Vertical section of the flower of the common Birthwort (*Aristolochia Clematitis*).— *Fig.* 998. The gynœcium and andrœcium of the same.——*Fig.* 999. Transverse section of the seed.

Order 2. CYTINACEÆ.—A small order of parasites which have no chlorophyll. The vegetative body is extremely reduced, there being no leaves. The stem produces either a single large flower or a compact inflorescence of small flowers. The vegetative part of the plants is often entirely enclosed in the tissues of the host plant, as in *Rafflesia*, which only ruptures the latter in order to produce the flower. This therefore appears to emerge from part of the host plant, usually the root. The flowers have a campanulate perianth with frequently succulent leaves; the stigmas and anthers occur in union to form a central column; the ovary is usually 1-celled.

The most conspicuous member of the order is *Rafflesia Arnoldi*, which is parasitic on the roots of a species of *Cissus* in Sumatra. Its flowers are three feet in diameter, and have a very fœtid odour.

Order 3. ARISTOLOCHIACEÆ.—The plants of this order are perennial herbs or climbing shrubs, with alternate simple leaves. The perianth is composed of three leaves which cohere to form a tube, at the bottom of which are placed the stamens. The ovary is inferior, 6-celled, with axile placentas. In *Asarum* the stamens are free; in *Aristolochia* they are fused with the styles to form a column surmounting the ovary. The stigmas thus are situated above the stamens (*fig.* 998).

In *Asarum* there are three scales alternating with the three lobes of the perianth. These may represent a rudimentary corolla.

Series 4.—*Micrembryeæ.*

In this group the embryo is very minute; the ovary may be monocarpellary, apocarpous, or syncarpous; the ovules are generally solitary in each carpel, rarely two or more. There is a bulky albumen which is sometimes perisperm in addition to endosperm.

Order 1. PIPERACEÆ.—The plants of this order are herbs or shrubs, with a jointed stem bearing simple leaves. In some cases there are stipules which are interpetiolar, and sometimes enclose the buds. The flowers are borne in spikes upon a swollen axis or spadix, or in racemes. The outer flowers have no perianth. The stamens are in two whorls of three each, but in some cases four of them are abortive. The pistil is tricarpellary, but sometimes two of the carpels are suppressed. The ovary is 1-celled, and contains a single orthotropous ovule. The fruit is succulent, and both endosperm and perisperm are present in the seed. In some species the flowers are diclinous.

The plants of this order are chiefly remarkable for acrid, pungent, aromatic, and stimulant properties. These qualities are principally found in their fruits, and are essentially due to the presence of an acrid volatile oil and resin. Some are narcotic, and others are reputed to be astringent and febrifugal.

Order 2. CHLORANTHACEÆ.—A small tropical order of plants with opposite leaves, whose stipules are united at their bases. The flowers have a rudimentary perianth, and an inferior ovary which forms a succulent fruit. The seeds have no perisperm; the endosperm is fleshy.

Order 3. MYRISTICACEÆ.—The plants of this small order are trees with alternate exstipulate dotted leaves. The flowers are diœcious; the perianth is 3-lobed, the stamens vary in number from three to eighteen and are monadelphous; the pistil has a single carpel and bears a solitary anatropous ovule. The fruit is pear-shaped and dehisces by both sutures. The seed is of considerable size and is invested by an aril, which is irregularly branched. The endosperm is ruminated.

Myristica moschata is the Nutmeg. Its aril forms the spice called *mace*.

Order 4. Monimiaceæ.—The plants of this order are tropical shrubs with opposite leaves and diclinous perigynous flowers. The anthers of some of them open by recurved valves. The pistillate flowers usually contain rudiments of stamens.

Series 5.—*Daphnales.*

The plants of this group are in most cases trees or shrubs, with a sepaloid perianth, which is sometimes 2-seriate. The stamens are perigynous; isostemonous or diplostemonous, or occasionally fewer than the perianth leaves; the ovary is generally monocarpellary; if syncarpous it has two to four loculi; the ovules are solitary, or in pairs in each loculus.

Fig. 1000.

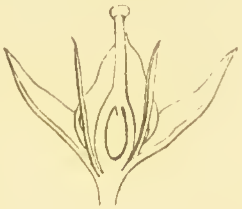


Fig. 1000. Vertical section of the female flower of *Laurus nobilis*, the Sweet Bay.

Order 1. Lauraceæ.—The plants of this order are arborescent, and the leaves in most cases evergreen. They have usually no stipules, and are simple and entire. In many cases they contain reservoirs of ethereal oil. The inflorescence is a panicle. The flowers are small and regular; the receptacle becomes cup-shaped, and carries up the perianth and stamens, so that the flower is perigynous. The flower is in some cases trimerous, in others dimerous or tetramerous. The perianth, though sepaloid, is in two series; the stamens are in either three or four whorls, of which some are developed as staminodes. The anthers dehisce by upturned valves. Some of the stamens bear glandular appendages. The pistil is tricarpellary, and the ovary is unilocular, and bears a single suspended ovule. The fruit is a berry or a drupe, sometimes partly enclosed in a succulent portion of the receptacle. The seeds are exalbuminous.

The position of this order has been much debated. Though it is generally placed here, its 2-seriate perianth suggests that it should not be included among the Monochlamydeæ. It is considered by some botanists to be allied to *Menispermaceæ*, while others consider its affinities to be rather with the *Polygonaceæ*.

Laurus nobilis, the Sweet Bay, has diclinous flowers.

Order 2. PROTEACEÆ.—This is an order which is most abundantly represented in Australia, but is present also in South Africa and South America. The plants are arborescent, and bear a number of evergreen leaves of a more or less dry, leathery consistency. Their form is extremely variable, sometimes both simple and compound leaves occurring on the same plant. There are no stipules. The flowers are arranged in crowded inflorescences, and sometimes are brilliantly coloured. They are occasionally diclinous. Their symmetry is tetramerous; the perianth has only one whorl, and there is only a single whorl of stamens; they have only one carpel. They are zygomorphic in some species. The perianth leaves are valvate in æstivation, and may be free or slightly coherent at their bases. The ovary is borne upon a short gynophore, and contains several ovules. The fruit is in some cases a follicle; in others a nut. The seeds are exalbuminous.

These plants are chiefly remarkable for the beauty or singularity of their flowers and their evergreen foliage. The fruits and seeds of some species are eaten; and the wood is largely employed at the Cape and in Australia for burning, and occasionally for other purposes; thus, that of *Protea grandiflora* is used at the Cape of Good Hope for wagon-wheels, hence the plant is named Wagenboom. The seeds of *Macadamia ternifolia*, a native of Queensland, are edible.

FIG. 1001.

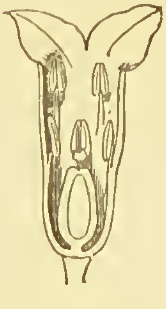


Fig. 1001. Vertical section of the flower of a species of *Daphne*.

Order 3. THYMELACEÆ.—The plants of this order are usually trees or shrubs, with a very tough bark. The leaves are entire, alternate, and exstipulate. The flowers are most frequently perfect. A receptacular tube, which is usually coloured, bears on its edge the calyx or perianth, which consists of four or five imbricated sepals. Occasionally a number of small scales represent the corolla. The stamens vary in number, but are typically in two whorls isomerous with the calyx. In this case they are situated at different levels (*fig.* 1001). The ovary is superior, 1-celled, with solitary pendulous ovule. The fruit is usually a berry. The radicle of the seed points upwards. There is generally no endosperm, though occasionally a very small quantity is present.

Daphne Mezereon and *D. laureola* are British plants occurring in woods.

Order 4. PENÆACEÆ.—A small order of evergreen shrubs, found only at the Cape of Good Hope. They are closely allied to *Proteaceæ*, but differ from them in having a 4-celled ovary which becomes a 4-celled fruit.

Order 5. ELÆAGNACEÆ.—The plants of this small order are remarkable for the silvery or scurfy appearance of their leaves, which is due to the peculiar peltate hairs with which they are covered. The plants are trees or shrubs; the leaves are entire and exstipulate. The flowers are frequently diclinous. The stamens are in some species in two whorls, but in others the outer whorl is not developed. The fruit is an achene, which becomes surrounded by and embedded in the persistent fleshy receptacle. There is a single ovule, which is erect with the radicle inferior or turned downwards.

Hippophaë rhamnoides, the Sea Buckthorn, is the only British representative of the order.

Series 6.—*Achlamydosporeæ*.

The plants of this division have a unilocular ovary with one to three ovules, which are most frequently without integuments. The seeds contain albumen, but have no testa.

Order 1. LORANTHACEÆ.—The plants of this family are partially parasitic upon various trees, but they contain chlorophyll and do no injury to their hosts. The flowers are sometimes perfect, sometimes diclinous, in which case they may be diœcious. The perianth consists of four to eight leaves; the stamens are opposite to its lobes and equal to them in number. The ovary is inferior and 1-celled, with a central placenta. The placenta becomes adherent to the wall of the ovary, and in the resulting fleshy mass from one to six embryo sacs are developed, only one of which is fertile. Each of them probably represents an ovule, but the differentiation is incomplete. There are no integuments to the ovule. The fruit is a berry and contains a single seed.

Viscum album is the Mistletoe, which forms conspicuous bunches on the Apple, Poplar, &c. It is probable that the relation between the two plants is one of symbiosis rather than of parasitism.

Order 2. SANTALACEÆ.—The plants of this order were until recently termed *root-parasites* from the fact that their roots come into contact with the roots of other plants growing near them, and set up there a peculiar relationship. On the root at the point of contact a small nodular swelling is developed, and from this certain cellular outgrowths or haustoria penetrate the root of the host plant and set up a very close fusion of the tissues. It is probable that the plants are of mutual assistance, and the relationship is accordingly one of symbiosis. Some of the plants of the order are shrubs, others are herbs. The perianth is gamophyllous, and a stamen stands opposite to each segment. The ovary is inferior and 1-celled, but consists of three carpels. It bears a free central placenta, in which are three ovules without integuments. The fruit is a nut or a drupe, and the seeds, which have no testa, contain endosperm.

Order 3. BALANOPHORACEÆ.—These plants are parasites with amorphous fungoid-looking stems without leaves. They contain scarcely a trace of chlorophyll and are generally yellow in colour. They live in the tissues of their hosts, only emerging at different places to flower. They are diclinous, and the staminate flowers are the largest; they possess a 3—5-lobed perianth and from one to five stamens. The pistillate flowers are very minute, often having no perianth. The ovary is inferior, 1-celled, and contains a solitary pendulous ovule, which is without integument except in *Cynomorium*.

Series 7.—*Unisexuales*.

The plants of this group have diclinous or unisexual flowers. The ovary may be composed of one carpel or may be syncarpous. The ovules are solitary or in pairs in the ovary or in each loculus of it. The leaves are generally stipulate and the perianth is often absent. If present it is sepaloid. The styles are equal in number to the carpels and are often lobed.

Order 1. EUPHORBIACEÆ.—The plants of this order are of very varied habit, and include herbs, shrubs, and trees. Some of them are extremely like various species of *Cactus*, having a swollen fleshy stem, with the leaves either very small and deciduous or metamorphosed into spines. In most of them there is a complex system of laticiferous tubes, which may consist of single branched cells or cœnocytes, or may be due to the fusion of cells. The latex is very frequently milky in appearance and is always acrid. The inflorescence is very varied. The flowers are always diclinous and frequently diœcious. They exhibit all possible degrees of reduction. In some the perianth consists of both calyx and corolla, in others there is no corolla; some are entirely achlamydeous. There may be only a single stamen, as in *Euphorbia*; the andrœcium may be isostemonous or diplostemonous; or the stamens may be very numerous owing to repeated branching, as in *Ricinus*. In some genera the staminate inflorescence is amentaceous. The gynœcium is typically tricarpellary, but there may be only a single carpel, or two, or many. It is always syncarpous, if there is more than one carpel, and the ovary then contains as many loculi as there are carpels. In each loculus there are one or two pendulous ovules whose micropyles are in most cases turned upwards and outwards. The seed bears a caruncle which is placed above the micropyle. The fruit is a schizocarp, splitting into its separate carpels, which form cocci and are indehiscent or open septicidally.

Fig. 1002.

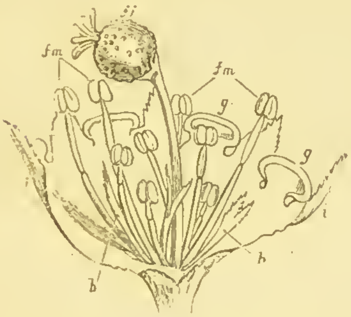


Fig. 1003.

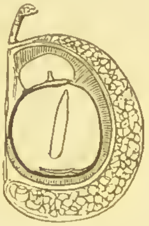


Fig. 1002. Monœcious inflorescence of a species of *Euphorbia*. *i*. Involucre, a portion of which has been removed in front. *g*, *g*. Glands on the divisions of the involucre. *b*, *b*. Scales or bractlets at the base of the flowers. *fm*, *fm*. Staminate flowers, each consisting of a stamen supported on a pedicel, to which it is articulated. *ff*. Pistillate flower, supported on a stalk. From Jussien.——*Fig*. 1003. Vertical section of the pericarp and seed of a carpel (*coccus*) of a species of *Euphorbia*.

The best known British genus is *Euphorbia*; the British species are usually small herbs whose inflorescence is their most characteristic feature. The general inflorescences are cymose umbels, which are composed of a number of partial inflorescences known as *cyathia*. These are cup-shaped structures formed of a number of coherent bracts in the interior of which are a number of staminate flowers surrounding a central pistillate one. The involucre formed by these bracts is in some of the exotic species brilliantly coloured, and is notched or lobed. Upon its edges between the lobes are placed some half-moon-shaped glands which also may be coloured. The staminate flowers are arranged in groups of five, and each consists of a single stamen which is mounted on a short stalk and stands in the axil of a bract. In some of the Australian species there is a rudimentary perianth situated at the junction of the stamen and the stalk. When the perianth is absent the point of junction is still conspicuous. The pistillate flower in the centre is seated on a stalk which grows after the flower is fertilised, and causes the fruit to protrude over the edge of the involucre and to hang down over the side. It has three carpels on a short gynophore, and in the British genera has no perianth, but in *Euphorbia palustris* the latter is sometimes present in a very rudimentary condition. In *E. splendens* the stalk of the flower is of a different colour from the gynophore on which the ovary is seated. The fruit is a schizocarp consisting of three cocci.

It is this genus which presents the greatest variety of habit. The British species include annual and perennial herbs, the stems of the latter being suffruticose. Shrubs are known in South Europe, but they are only of small size. It is mainly in Africa that the abnormal forms occur, especially those which resemble the Cacti in appearance.

Another common British genus is *Mercurialis*, which includes two species with apetalous flowers. The latter are diclinous, the staminate possessing several stamens, and the pistillate two carpels.

Ricinus, the Castor-oil plant, is monœcious; the staminate flowers have five perianth leaves and numerous stamens, the result of branching. The pistillate flower has three carpels with bifid styles. *Phyllanthus* (*Xylophylla*) bears phylloclades on which the flowers occur along the edges in the axils of small bracts. *Cœlebogyne* is peculiar in producing its embryo by a species of budding from the external surface of the embryo sac, the oosphere not being fertilised. *Anthostema* has a distinct perianth to its staminate flower, which, like that of *Euphorbia*, consists of a single stamen. *Buxus* has the micropyle of the seeds turned inwards. Its flowers are in glomerules, with a terminal pistillate and lateral staminate flowers. There is no latex in the tribe *Buxeæ*.

Order 2. BALANOPSEÆ.—This is a small order of New Caledonian plants closely allied to *Euphorbiaceæ*. They have their staminate inflorescence amentaceous. The ovary is imperfectly 2-celled, and contains two ovules in each loculus. The radicle is inferior.

Order 3. URTICACEÆ.—This order includes plants of very different external habit and appearance. The majority are trees or shrubs with stipulate leaves on long stalks. The leaves are generally hairy with very rough and in some cases stinging hairs. The tissue of the leaves frequently contains cystoliths. The inflorescence is varied; cymose clusters arise in pairs in many cases from the base of a dwarf shoot which stands in the axil of a leaf. In other cases catkins are met with. The flowers are usually diclinous; the perianth is always sepaloid and often very minute; the stamens are equal in number to the segments of the perianth and opposite to them. The ovary is composed of one or of two carpels, and is usually unilocular with a single ovule. The fruit is an achene in some cases, in others a drupe; in others the true fruits are aggregated together to form a sorosis or a syconus. The seeds are albuminous.

Fig. 1004.

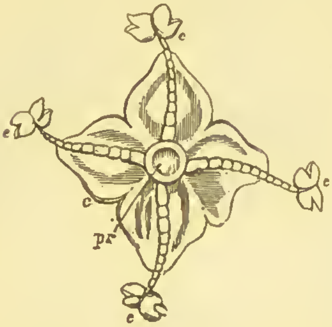


Fig. 1005.

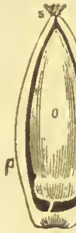


Fig. 1004. Staminate flower of the Small Nettle (*Urtica urens*). *c.* Calyx. *e*, *e*, *e*, *e*. Stamens, with 2-celled anthers. *pr.* Rudimentary ovary.——*Fig.* 1005. Vertical section of the ovary of the pistillate flower of the same. Wall of the ovary. *s.* Stigma. *o.* Ovule.

The order comprises the following tribes, which by many botanists are considered separate Natural Orders.

1. *Urticeæ.*—Generally these are herbaceous plants with simple stipulate leaves, which like the stems are often covered with stinging hairs. The form of inflorescence varies, but frequently is a catkin. Clusters of somewhat irregular composition also occur. The flowers are diclinous; the staminate ones have four stamens which in some species are arched over by the perianth segments and are released with some force by an elastic recoil of the filaments. The ovary is always monocarpellary and contains a single *orthotropous* ovule which is erect (*fig.* 1005). The perianth in the pistillate flower has its

two internal leaves larger than the others and the fruit is enclosed by them.

Urtica dioica and *U. urens* are the common Stinging-Nettles. *Parietaria*, the Pellitory, has no stinging hairs.

2. *Moreæ.*—The plants of this tribe are almost all arborescent and have a milky latex. The leaves are alternate. The flowers are diclinous, and the form of inflorescence either is a catkin or resembles a capitulum. The ovary is formed from two carpels, and has one ovule in each loculus if there are more than one. The ovules are pendulous (*fig.* 1009); the seed is albuminous.

FIG. 1006.

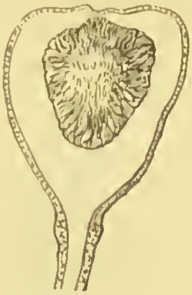


FIG. 1007.

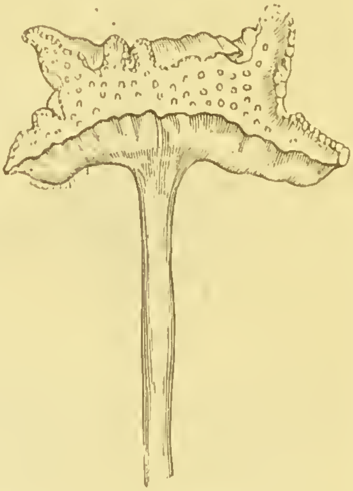


FIG. 1008.

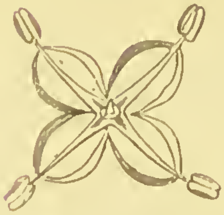


FIG. 1009.

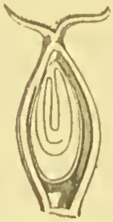


Fig. 1006. Hypanthodium of the Fig (*Ficus Carica*), showing pear-shaped fleshy receptacle bearing flowers on its inner surface.——*Fig.* 1007. Cœnanthium of a species of *Dorstenia*.——*Fig.* 1008. Staminate flower of the Black Mulberry (*Morus nigra*).——*Fig.* 1009. Vertical section of the ovary of the pistillate flower of the same.

Morus, the Mulberry, has a collective or aggregate fruit. The small drupes are enveloped in a perianth which becomes succulent, and as all the flowers are compressed together very closely, a sorosis is formed. *Ficus Carica* is the Fig. The so-called fruit is a syconus, formed of the concave receptacle or axis of the inflorescence, on which the flowers are seated. The concavity is so pronounced as to form an urn-like body almost closed at the apex by its involucral bracts. *Artocarpus incisa* is the Bread-fruit tree. Its fruit is a sorosis much like that of the Mulberry; the perianths and ovaries of the whole inflorescence become succulent, as does the axis in which the flowers are borne. *Dorstenia* resembles the Fig, but the receptacle becomes flattened with irregular upturned edges (*fig.* 1007). The staminate and pistillate flowers are sunk in this flattened expansion.

3. *Cannabineæ.*—The plants of this tribe are annual or perennial herbs with a fragrant odour. They have no milky latex. The staminate flowers are arranged in cymose inflorescences which are often paniculate. The perianth has five sepals and there are five stamens. The pistillate flower has an entire cup-like perianth which surrounds the base of the ovary. The seed is pendulous and curved; the embryo is also curved and there is no endosperm.

Fig. 1010.

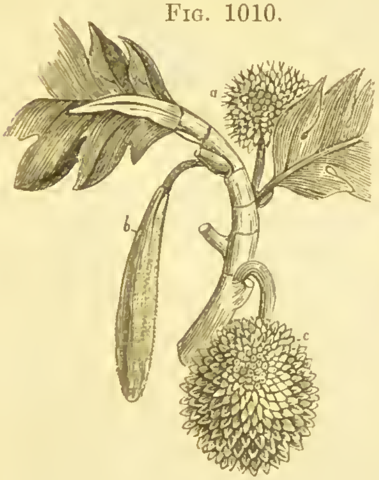


Fig. 1011.

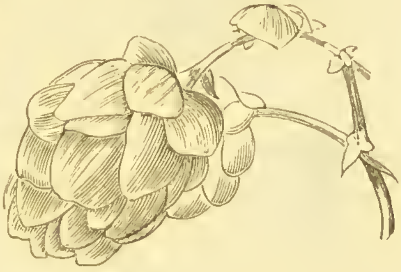


Fig. 1010. Branch of the Bread-fruit tree (*Artocarpus incisa*). *a, c.* Heads of pistillate flowers. *b.* Head of staminate flowers.——*Fig.* 1011. Strobile of the Hop (*Humulus Lupulus*).

Humulus Lupulus is the Hop. The pistillate flowers are arranged in cone-like inflorescences, the large leafy structures of which, in whose axils the flowers arise, are really the stipules of the bracts, the blades of which are suppressed. The flowers are borne in pairs on each side of a rudimentary shoot which arises in the axil of the bract. *Cannabis sativa* is the Hemp; the inflorescence is not cone-like. The shoot which is rudimentary in the Hop is developed into a leaf-bearing organ, and from it a single pistillate flower arises on each side. The bracts are not so large as in the Hop.

4. *Ulmeæ.*—This tribe includes a number of trees and shrubs with oblique leaves arranged on two orthostichies. They have stipules when young, but the latter soon fall off. The plants do not contain latex. The inflorescences are clusters or glomerules and are borne in the axils of the ordinary leaves. The flowers are generally perfect and have a uniseriate gamophyllous perianth of from four to six segments. The stamens are equal in number and opposite to the segments; the pistil has two carpels, but the fruit is generally 1-celled and contains a solitary ovule.

Ulmus, the Elm, has a samaroid fruit; the branching is sympodial. *Celtis* has polygamous flowers, and a drupaceous fruit.

FIG. 1012.

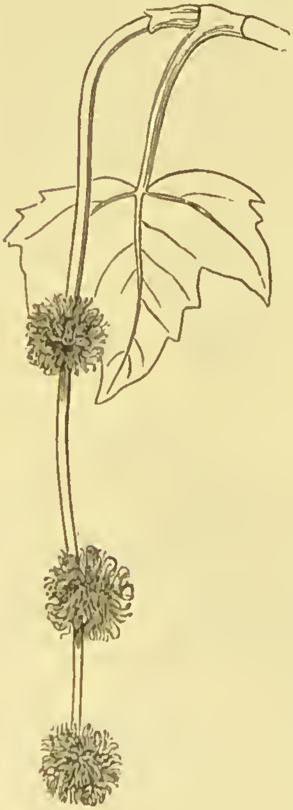


Fig. 1012. Branch of the Plane tree (*Platanus orientalis*), with amentaceous heads of achlamydeous female flowers.

Order 4. PLATANACEÆ.—This order is classed among the Calyciforæ by many botanists on account of its resemblances to some of the *Saxifragaceæ*. It includes a number of trees with large lobed leaves and ochreate stipules. They are peculiar in possessing scale bark which is shed in patches or large scales during the early part of the year. The flowers are monœcious and are collected into crowded globular heads resembling capitula, which are pendant in slender axes (*fig.* 1012). The perianth is insignificant, but traces of both calyx and corolla can be detected; the staminate flower has only a few stamens; the pistillate one has four free carpels with one pendulous orthotropous ovule in each. The fruit is a caryopsis or nut, but from the character of the inflorescence the number of them is so great and they are so closely packed together that they become a globular, almost woody, sorosis.

Order 5. Leitneraceæ.—A small order occurring only in Florida. The flowers are dielinous, and there is no perianth. The stamens are numerous, the ovary is 1-celled and contains a solitary ovule. The seed has the radicle superior and contains a scanty amount of endosperm.

Order 6. Juglandaceæ.—The plants of this order are trees with scattered imparipinnate leaves without stipules. The flowers are monœcious and are borne in catkins. The staminate flowers have indefinite stamens which are surrounded by a 2—4-leaved perianth; they lie in the axil of a bract and there are two bracteoles slightly above the latter. The bracts, bracteoles, and perianth leaves become united together. The catkins of the pistillate flowers are terminal and few-flowered. They have a superior 4-leaved perianth surrounding two carpels. The bracts and bracteoles are the same as in the staminate flower. The fruit is known as a *tryma*; it is a modification of a drupe, for the succulent portion is made up of the outer layers of the pericarp fused with the bracteoles and bracts. The fruit contains a single orthotropous ovule, which becomes a lobed exalbuminous seed.

Fig. 1013.

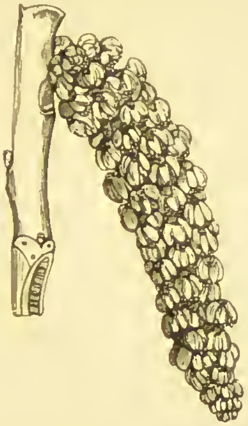


Fig. 1014.

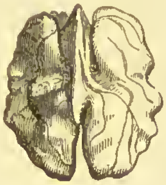


Fig. 1013. Staminate amentum of the Walnut tree (*Juglans regia*): the flowers are separated by scaly bracts.——*Fig.* 1014. Seed of the Walnut tree.

Juglans, the Walnut, has the loculus of the stone divided internally into two parts by a true but incomplete partition, formed of the inturned edges of the carpels. Each half is further divided by several false partition walls, which project from the internal surface of the stone. The seed becomes lobed according to the disposition of these septa.

Order 7. CASUARINACEÆ.—This order includes a number of Australian and East Asian trees which have long fine apparently leafless branches, very considerably furrowed. The leaves are really present but take the form of toothed sheaths, resembling those of the Horsetails. The branches are verticillate. The flowers are diclinous and are arranged in catkins or short spikes. The staminate flowers consist of a single stamen surrounded by two perianth leaves, below which are two bracteoles. The pistillate flowers have the two bracteoles, but are otherwise naked; the ovary is 1-celled and contains two orthotropous ovules. The bracteoles of the several flowers of an inflorescence become woody, so that the fruit simulates the appearance of a small Fir-cone.

Casuarina is peculiar in certain of its processes of reproduction. In the development of the ovule, two original archesporial cells are formed, and these divide to form a mass of sporogenous tissue invested entirely by a tapetum. Most of the cells of this tissue may be recognised as megaspores, and nearly all of them develop their gametophytes. The latter differ from the normal angiospermous gametophyte in not producing antipodal cells. The divisions of the egg apparatus also are abnormal, the sister cells of the oosphere resembling ventral canal cells rather than synergidæ. The number of divisions also varies. Many of the megaspores remain altogether sterile, some of them elongating in the direction of the chalaza of the ovule. Among the sterile tissue peculiar tracheïd-like cells occur. The gametophyte of only one of the megaspores bears an oosphere which becomes fertilised. The pollen tube does not take the ordinary course during its development. Instead of entering the ovary by the style it makes its way into the cavity through the wall, and enters the placenta, whence it reaches the ovules by way of the chalaza, burrowing through the solid tissue of the nucellus. It passes towards the fertile megaspore through one of the sterile ones. The tube itself does not enter the megaspore, but extrudes into it the male gamete, which fuses with the oosphere from below. This mode of fertilisation has been termed *chalazogamic*.

Order 8. MYRICACEÆ.—A small order of trees or shrubs. The flowers are diclinous, often diœcious, and are borne in catkins. There is no perianth, but there are bracteoles under the flowers. The staminate flowers have from four to sixteen stamens; the pistillate flower has a bicarpellate 1-celled ovary, with a single orthotropous ovule. The fruit is a false drupe, the bracteoles fusing with the pericarp, and all but the inner layer of the latter becoming succulent.

Order 9. CUPULIFERÆ.—The plants of this order also are trees or shrubs, with spiral phyllotaxis, the leaves being arranged in two rows, and having deciduous stipules. They have small diclinous flowers, which are usually monœcious. The perianth is either absent or inconspicuous. The staminate flowers are arranged in catkins, and consist of a few stamens in the axil of a bract. When a perianth is present the stamens are opposite to its segments. The pistillate flowers have the perianth superior when it is present. These flowers are in some cases arranged in catkins, but not in all. They are frequently solitary, and are then surrounded by an involucre of a varying number of bracts, which after flowering is over undergo a considerable development, and sometimes even enclose the fruit. They form the *cupule*, which gives the name to the order, and is one of its most characteristic features except in the tribe *Betuleæ*. The fruit is a nut. It is developed from a 2—3-locular ovary, which has one or two pendulous ovules in each cell. Only one cell and usually only one ovule persist. The seed is exalbuminous.

By Bentham and Hooker the order is divided into three tribes or sub-orders as under:

1. *Betuleæ*.—The flowers are monœcious, and both staminate and pistillate ones are arranged in catkins. The latter are composed of several dichasia, which are placed spirally along the axis. There is sometimes a perianth to the staminate flower, which then consists of four coherent leaves enclosing four stamens. The pistillate flowers are naked; the ovary has two cells, with a single pendulous ovule in each. There are two styles. The bracts and bracteoles are united to form a 3- or 5-lobed scale, which does not adhere to the fruit. The latter has no cupule.

Alnus is the Alder; in most species it shows three stages of formation of the flowers and fruit: young catkins developed the year before they flower; older ones blooming before the leaves are put out; and dried fruits of the preceding year. The 5-lobed scales of the pistillate flower are woody and do not fall off, so that the catkin has the appearance of a small cone. There are two nuts in the axil of each scale. *Betula* is the Birch; it bears its staminate catkins in the autumn, and the pistillate ones in the spring. The staminate flowers have only two stamens. The 3-lobed cover scales of the pistillate flower fall off; each has 3 winged nuts in its axil.

2. *Coryleæ*. The flowers are monœcious. The staminate flowers are borne in cylindrical catkins; each is subtended by a scale or bract. There is no perianth, and the stamens vary

from four to eight in number. The pistillate flowers are arranged in dichasia grouped together into short catkins. Each dichasium consists of two flowers, and is subtended by a cover-scale or bract. The lower scales of the catkin have no flowers in their axils. The flowers have a small superior perianth, and a pistil of two carpels with long styles. There are two cells in the ovary, each of which contains an ovule. In the development of the fruit, which is a nut, only one loculus and a single ovule persist. Each nut is surrounded by a cupule, which is foliaceous, and composed of the bract and bracteoles belonging to the flower.

Fig. 1015.

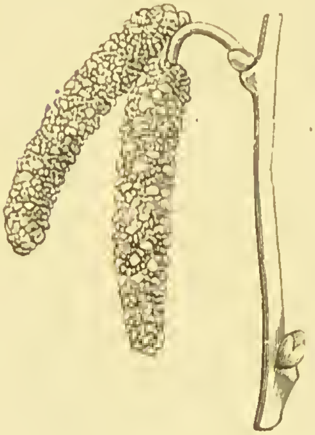


Fig. 1016.

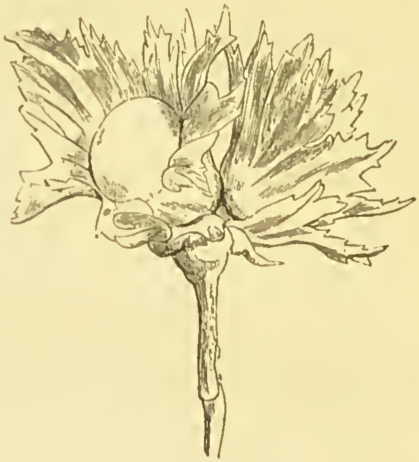


Fig. 1015. Staminate catkin of the Hazel (*Corylus*).—*Fig.* 1016. Fruit of the Hazel, with a foliaceous cupule at its base.

Corylus is the Hazel. Its staminate flowers consist of four forked stamens situated in the axil of a bract which bears two bracteoles. The pistillate catkin resembles in appearance an ordinary vegetative bud, but the red stigmas of the flowers protrude from its apex. The cupule completely invests the nut.

Carpinus is the Hornbeam. There are four to ten forked stamens in the axil of the bract. The cupule is 3-lobed, and only the extreme base of it surrounds the nut, which appears as if placed in the axil of a 3-lobed leaf.

3. *Quercineæ.*—The flowers are monœcious. The staminate flower has a 4—6-cleft gamophyllous perianth, and the stamens, which are not forked, are numerous. The pistillate

flowers have a superior perianth, which consists of two whorls of three leaves each. There are three carpels, each with its stigma ; the ovary is divided into three cells at its lower part, and each cell contains two ovules, which are anatropous. In the fruit, a nut, all are suppressed but one cell and one seed. The nut is surrounded at its base by a cupule, formed as in the *Coryleæ* from the bracts and bracteoles. The cupule may completely enclose the nut, or may only invest its base. In the former case it divides into a number of valves to allow the fruit to escape. A cupule may surround a single flower or several.

Fig. 1017.

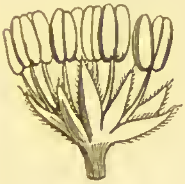


Fig. 1018.

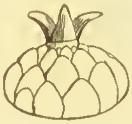


Fig. 1019.

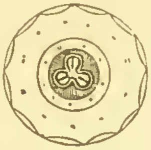


Fig. 1020.

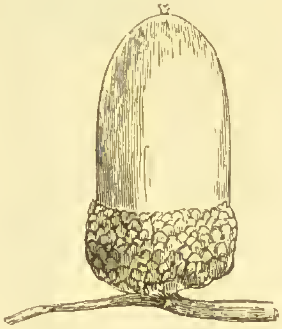


Fig. 1017. Staminate flower of a species of Oak (*Quercus*).——*Fig.* 1018. Pistillate flower of the same.——*Fig.* 1019. Transverse section of the pistillate flower.——*Fig.* 1020. Fruit of the Oak (*Quercus*), with cupule at its base.

Quercus, the Oak, has long pendulous staminate catkins, in some species very sparsely flowered. The cupule is cup-shaped, and encloses the base only of the nut or acorn, which is developed from the single median flower of five originally present in the axil of the bract. The cupule is covered externally with scales, which have been interpreted as leaf structures, or as hairs.

Fagus, the Beech, has pendulous staminate catkins, each consisting of a fringed perianth with six to twenty stamens. The pistillate catkins are erect and bear two flowers only. There are three carpels, surmounted by a 6-leaved perianth. The cupule surrounds the two flowers and completely encloses them.

Castanea, the Spanish Chestnut, has one form of catkin only, which usually bears staminate flowers at the apex and pistillate ones at the base. The cupule is like that of Fagus, and completely encloses the three nuts. Both staminate and pistillate flowers have a 6-leaved perianth, and the latter have six carpels, of which only one develops.

In the greater part of this order the ovules and to a certain extent the divisions of the ovary are not developed till after pollination.

Certain of the genera, viz. *Alnus*, *Betula*, *Corylus*, and *Carpinus*, resemble *Casuarina* in showing the pollen tube reaching the oosphere by way of the chalaza instead of the micropyle.

The British plants belonging to the three tribes of the Cupuliferæ, together with the indigenous members of the Myricaceæ and the Salicineæ, have been grouped together by many English botanists into a single large order, the *Amentiferæ*, the characteristic feature of which is that the catkin is the dominant form of inflorescence.

Fig. 1021.

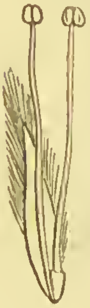


Fig. 1022.

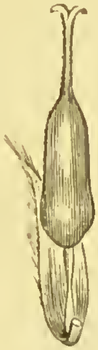


Fig. 1021. Staminate flower of a species of Willow (*Salix*), with two stamens and a single bract at their base.——*Fig* 1022. Pistillate flower of the same with bract at the base, and a solitary stalked ovary and style surmounted by two stigmas.

By Babington the order is subdivided as under:—

Sub-order 1. *Salicaceæ.*—Carpels superior; ovary 1-celled, many-seeded; seeds hairy.

Sub-order 2. *Betulaceæ.*—Carpels superior; ovary 2-celled, 2-seeded; seeds not hairy.

Sub-order 3. *Myricaceæ.*—Carpels superior; ovary 1-celled, drupaceous.

Sub-order 4. *Cupuliferæ.*—Carpels inferior; ovary 2- or more celled, invested by a cupule.

Series 8.—*Ordines anomali.*

Order 1. Salicineæ.—The plants of this order are trees or shrubs with simple alternate leaves with stipules which are sometimes deciduous. The flowers are diœcious, and are arranged in catkins which fall off the trees intact. The staminate catkins, which are pendulous, consist of a large number of flowers having no perianth. There are several stamens in the axil of a bract. The pistillate flowers are arranged similarly in catkins, but the latter are erect. Each flower is subtended by a bract; it is achlamydeous, and consists of a bicarpellate ovary containing a number of ovules arranged on parietal placentas. The seeds bear a tuft of hairs at their bases; they are exalbuminous. There is a disc or nectary in each flower.

Salix, the Willow, has its bracts undivided; there are only two stamens. *Populus*, the Poplar, has fimbriated or fringed bracts; the stamens are from four to thirty in number. There is a rudimentary perianth.

FIG. 1023.

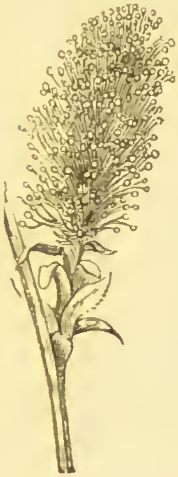


FIG. 1024.

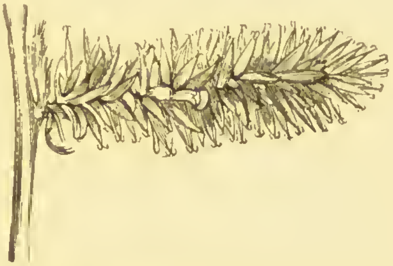


Fig. 1023. Staminate amentum or catkin of a species of Willow (*Salix*). —*Fig.* 1024. Pistillate or carpellary amentum of a species of Willow, with bracts between the flowers.

Order 2. LACISTEMACEÆ.—A small order of tropical plants confined to America. The flowers are in catkins; there is a perianth, a single stamen, and a superior 1-celled ovary with numerous ovules. There are only two genera.

Order 3. EMPETRACEÆ.—A small order which is held by some botanists to be allied to the *Euphorbiaceæ*. The flowers are diœcious; the staminate flowers have six perianth leaves in two whorls, and three stamens; the pistillate ones have a similar perianth and an ovary divided into six to nine loculi, each containing a solitary erect ovule. The fruit is drupaceous. The plants are evergreen shrubs with linear wiry leaves.

Order 4. CERATOPHYLLACEÆ.—A small order of submerged aquatic plants with no roots but with whorls of very finely divided leaves. The flowers are minute, monœcious, and axillary. There are six to twelve perianth leaves enclosing, in the staminate flower, twelve to twenty stamens; and in the pistillate one a single carpel which contains a pendulous, orthotropous ovule. The fruit is a nut, which in some species bears on each side and at its apex a peculiar prominence or horn, from which the common name of the order, 'Hornwort,' is derived.

Artificial Analysis of the Orders in the Sub-class.

MONOCHLAMYDEÆ OR INCOMPLETÆ.

(Modified from Lindley.)

1. Achlamydeous Flowers.

A. Leaves stipulate.
a. *Flowers unisexual.*
Ovary 1-celled.
Ovules numerous . . . . . . *Salicaceæ.*
Ovules 1—2.
Ovule erect . . . . . . *Myricaceæ.*
Ovule pendulous . . . . . *Platanaceæ.*
Ovary 2- or more celled.
Seeds few, not winged . . . . . *Euphorbiaceæ.*

b. *Flowers hermaphrodite.*
Carpel solitary.
Ovule erect. Embryo with endosperm and perisperm . . . . *Piperaceæ.*
Ovule suspended. Embryo with endosperm *Chloranthaceæ.*

B. Leaves exstipulate.
a. *Flowers unisexual.*
Ovules very numerous . . . . . *Podostemaceæ.*
Ovules solitary or very few.
Flowers naked.
Ovary 1-celled . . . . . . *Myricaceæ.*
Flowers within an involucre.
Anther-valves slit.
Embryo on the outside of the albumen . *Monimiaceæ.*
Embryo enclosed in the albumen . . *Euphorbiaceæ.*

b. *Flowers hermaphrodite.*
Embryo with endosperm . . . . . *Piperaceæ.*
Embryo without endosperm . . . . *Podostemaceæ.*

2. Monochlamydeous Flowers.

A. Ovary inferior, or partially so.
a. *Leaves stipulate.*
1. Flowers hermaphrodite . . . . . *Aristolochiaceæ.*
2. Flowers unisexual . . . . . . *Cupuliferæ (Coryleæ).*

b. *Leaves exstipulate.*
1. Flowers hermaphrodite.
Ovary 3—6-celled. Ovules numerous . . *Aristolochiaceæ.*

Ovary 1-celled. Ovules definite.
Ovules with a naked nucellus. Leaves opposite . . . . *Loranthaceæ.*
Ovules with a naked nucellus. Leaves alternate . . . . . . *Santalaceæ.*
Ovules with integuments . . . . *Chenopodiaceæ.*

2. Flowers unisexual.

Amentaceous . . . . *Juglandaceæ.*

B. Ovary superior.

a. *Leaves stipulate.*

1. Flowers hermaphrodite.
a. Carpel solitary.
Stipules ochreate . . . . . . *Polygonaceæ.*
b. Carpels more than 1, combined . *Urticaceæ (Ulmeæ).*

2. Flowers unisexual.
a. Carpel solitary.
Embryo straight.
Sap watery. Stipules small. Seeds albuminous . . . . *Urticaceæ (Urticeæ).*
Embryo hooked.
Sap watery. Seeds without albumen *Urticaceæ (Cannabineæ).*
Sap milky. Seeds with albumen . *Urticaceæ (Moreæ).*
b. Carpels more than 1, combined.

Flowers amentaceous.
Seeds arillate.
Stamen 1 . . . . . . *Lacistemaceæ.*
Seeds not arillate . . . . . *Cupuliferæ Betuleæ).*
Flowers not amentaceous . . . . *Euphorbiaceæ.*

b. *Leaves exstipulate.*

1. Flowers hermaphrodite.
a. Carpel solitary.
Anther-valves recurved . . . . . *Lauraceæ.*
Anthers slit.
Leaves covered with scales . . . *Elæagnaceæ.*
Leaves not so covered.
Calyx long or tubular.
Hardened at base . . . . *Nyctaginaceæ.*
Not hardened in any part.
Stamens in the points of the sepals *Proteaceæ.*
Stamens not in the points of the sepals . . . .

Calyx short, not tubular, or but slightly so.	
Flowers in involucels	*Polygonaceæ.*
Flowers not in involucels.	
Calyx dry and coloured	*Amarantaceæ.*
Calyx herbaceous or succulent.	
Stamens hypogynous or nearly so	*Chenopodiaceæ.*
b. Carpels more than 1, either distinct or combined.	
Carpels distinct	*Phytolaccaceæ.*
Carpels combined.	
Seeds exalbuminous.	
Calyx tubular.	
Ovary 4-celled	*Penæaceæ.*
Calyx tubular, or imperfect	*Podostemaceæ.*
Seeds albuminous	*Phytolaccaceæ.*
2. Flowers unisexual.	
a. Carpels solitary, or quite distinct.	
Calyx tubular.	
Anthers opening longitudinally	*Myristicaceæ.*
Calyx not tubular.	
Seeds exalbuminous. Embryo straight.	
Leaves verticillate	*Ceratophyllaceæ.*
Leaves minute, verticillate	*Casuarinaceæ.*
Seeds albuminous.	
Embryo curled round the albumen	*Chenopodiaceæ.*
Embryo straight	*Monimiaceæ.*
b. Carpels more than 1, combined.	
Ovules indefinite.	
Leaves with pitchers	*Nepenthaceæ.*
Ovules definite.	
Fruit fleshy. Seeds ascending	*Empetraceæ.*
Fruit dry. Seeds suspended	*Euphorbiaceæ.*

Root Parasites (Rhizogens of Lindley).

A. Ovary inferior. Ovules solitary	*Balanophoraceæ.*
B. Ovary superior. Ovules indefinite.	
Anthers opening longitudinally	*Cytinaceæ.*

Monochlamydeous or Achlamydeous flowers also occasionally, or in some orders always, occur in plants belonging to the following orders of the Sub-classes Polypetalæ and Gamopetalæ :—

Sub-class 1. Polypetalæ :—

Series 1. Thalamifloræ :—*Ranunculaceæ*, *Menispermaceæ*, *Papaveraceæ*, *Bixaceæ*, *Caryophyllaceæ*, *Paronychieæ*, *Sterculiaceæ*, *Byttneriaceæ*, and *Tiliaceæ*.

Series 2. Discifloræ:—*Malpighiaceæ*, *Rutaceæ*, *Chailletiaceæ*, *Geraniaceæ*, *Celastraceæ*, *Rhamnaceæ*, and *Anacardiaceæ*.

Series 3. Calycifloræ:—*Leguminosæ*, *Rosaceæ*, *Lythraceæ*, *Saxifragaceæ*, *Cunoniaceæ*, *Begoniaceæ*, *Datiscaceæ*, *Mesembryanthaceæ*, *Passifloraceæ*, *Myrtaceæ*, *Onagraceæ*, *Samydaceæ*, *Haloragaceæ*, *Combretaceæ*, *Hamamelidaceæ*, and *Araliaceæ*.

Sub-class 2. Gamopetalæ:—*Oleaceæ* and *Primulaceæ*.

Synopsis of the British Natural Orders of the Sub-class Monochlamydeæ.

A. Male flowers in catkins.	
Flowers diœcious.	
Male and female flowers in catkins.	
Fruit dry	*Salicaceæ*.
Fruit drupaceous	*Myricaceæ*
Flowers monœcious.	
Flowers all in catkins	*Cupuliferæ* (*Betuleæ*).
Male flowers only in catkins	*Cupuliferæ* (*Quercineæ*).
B. Flowers not in catkins.	
Ovary inferior. Fruit indehiscent.	
Stamens 4—5, epiphyllous	*Santalaceæ*.
Stamens 6—12, epigynous	*Aristolochiaceæ*.
Ovary 1, superior. Perianth sometimes absent.	
Fruit separating into several carpels. No perianth	*Euphorbiaceæ*.
Fruit not separating into carpels.	
Leaves stipulate.	
Stipules ochreate	*Polygonaceæ*.
Stipules free deciduous. Ovary 1-celled.	
Perianth 4—5-parted	*Urticaceæ*.
Perianth of female flower scale-like, open	*Urticaceæ* (*Cannabineæ*).
Stipules free deciduous. Ovary 2-celled	*Urticaceæ* (*Ulmeæ*).
Leaves exstipulate.	
Flowers monœcious or diœcious.	
Fruit fleshy. Stamens 2 or 3. Perianth scaly, imbricated	*Empetraceæ*.
Fruit dry.	
Stamens 3 or more. Perianth tubular	*Elæagnaceæ*.
Stamens 12—20. Perianth 10—12-cleft	*Ceratophyllaceæ*.
Flowers perfect or polygamous.	
Perianth 3—5-cleft, herbaceous. Fruit a utricle	*Chenopodiaceæ*.
Perianth 3-cleft, scarious	*Amaranthaceæ*.
Perianth tubular. Stamens perigynous	*Thymelaceæ*.

Sub-Class ~~II~~ I.—POLYPETALÆ.

Flowers with both calyx and corolla, the latter consisting of free petals. Both stamens and pistil usually present.

Series 1.—*THALAMIFLORÆ.*

The calyx generally consists of free sepals; the petals are often more numerous than the sepals; the stamens with few exceptions are hypogynous; the pistil may be either syncarpous or apocarpous.

FIG. 1025.

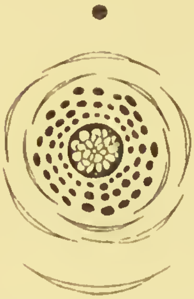


FIG. 1026.

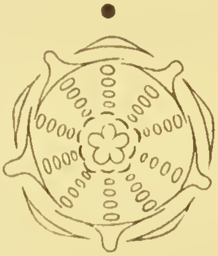


FIG. 1028.

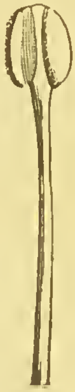


FIG. 1027.

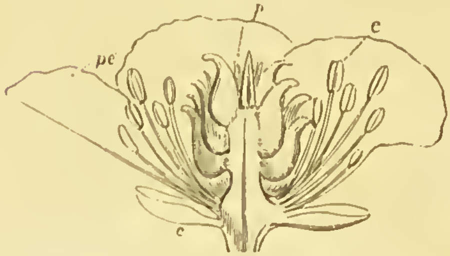


FIG. 1029.

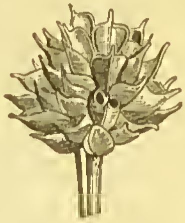


Fig. 1025. Diagram of the flower of a species of *Ranunculus.*——*Fig.* 1026. Diagram of flower of *Aquilegia.*——*Fig.* 1027. Vertical section of the flower of *Ranunculus acris.* c. Calyx. *pe.* Petals. *e.* Stamens. *p.* Carpels.——*Fig.* 1028.——Adnate anther of a Ranunculaceous plant.——*Fig.* 1029. Numerous follicles of *Trollius europæus.*

Bentham and Hooker divide the Thalamifloræ into six cohorts, each comprising several Natural Orders.

Cohort 1.—*Ranales.*

The flowers are generally either acyclic or hemicyclic; the perianth usually consists of calyx and corolla; the stamens are most frequently indefinite, and the pistil generally apocarpous. In some cases there is only one carpel; in a few others there is a syncarpous ovary with several loculi.

Order 1. RANUNCULACEÆ.—The plants are usually herbs, with frequently an acrid juice. The leaves, except in the tribe *Clematidæ*, are spirally arranged, and are exstipulate, but the leaf base is often sheathing. They are simple, but often somewhat deeply cut; as a rule they are palmate, but are pedate in *Helleborus*. The flowers, as a rule, have both calyx and corolla, but the latter is wanting in the genera *Caltha*, *Anemone*, *Thalictrum*, and *Clematis*; in these cases the sepals are usually coloured. In *Delphinium*, *Aconitum*, *Helleborus*, and *Eranthis* the calyx also is petaloid and the petals are represented as nectaries of different forms. The stamens are hypogynous, and indefinite in number; the carpels are generally numerous, and free or apocarpous. The arrangement of the floral leaves is sometimes eucyclic, as in *Aquilegia*; sometimes hemicyclic, the two whorls of the perianth showing their leaves regularly alternating with each other, while the stamens and carpels are arranged spirally along a conical thalamus, as in *Ranunculus*; or acyclic, all the floral leaves

FIG. 1030.

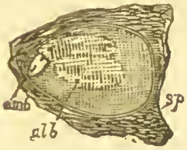


FIG. 1031.

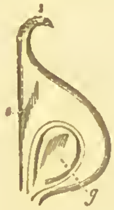


FIG. 1032.

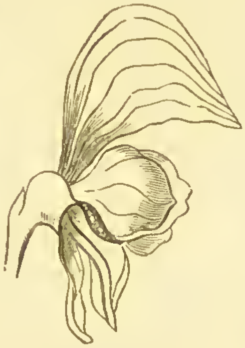


FIG. 1033.

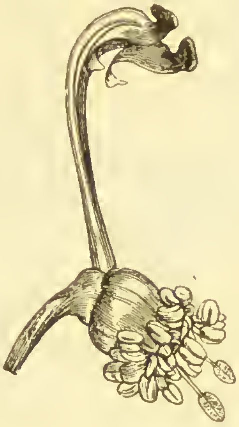


Fig. 1030. Vertical section of the seed of the Monkshood (*Aconitum*). *sp.* Coverings of the seed. *emb.* Embryo. *alb.* Albumen.——*Fig.* 1031. Vertical section of a carpel of *Ranunculus acris*. *o.* Ovary. *g.* Ovule. *s.* Stigma.——*Fig.* 1032. Flower of *Aconitum*.——*Fig.* 1033. The same with the calyx removed, showing the numerous stamens below, and two stalked somewhat horn-shaped petals above.

being placed in a spiral, as in *Helleborus*. When this is the case the angular divergence of the sepals is $\frac{2}{5}$; that of the petals $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, or $\frac{8}{21}$; and that of the stamens and carpels a higher fraction of the same series.

The flowers of this order show a great variety in the position and appearance of the nectaries. In *Ranunculus* these are placed at the base of the petals, and are covered by a minute scale; in *Helleborus* and *Eranthis* they are small tubular bodies occupying the positions of the petals; in *Aconitum* they are two modified petals which are covered over by the large hooded sepal; in *Thalictrum* they are on the stamens. It is held by some botanists that the order is to be regarded as without a true corolla, the so-called petals being transformed stamens, as are also the nectaries. The fruit in this order is usually an etaerio of achenes, but a cluster of follicles occurs in the tribes *Helleboreæ* and *Pæoneæ*. In *Actæa* there is a single carpel, which becomes a baccate fruit. In *Hydrastis* each carpel becomes fleshy as it ripens. In *Nigella* the pistil is syncarpous, and the fruit is a thin-walled capsule, containing several loculi. The seeds are albuminous, and the embryo is minute.

FIG. 1034.

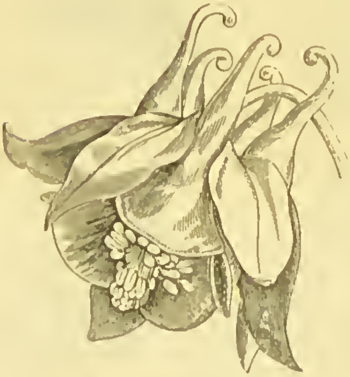


Fig. 1034. Flower of *Aquilegia*.

The order is divided into the following tribes:—

1. *Clematideæ.*—These are generally shrubby plants, many of which climb by means of their petioles. The plants of this tribe differ from all the other tribes by possessing opposite leaves and a valvate calyx. The petals are absent, and the fruits are achenes. In some species the latter bear long feathery styles.

2. *Anemoneæ.*—There are no petals; the calyx is usually coloured, and there is often a foliaceous involucre a little below the flower. The leaves are radical or alternate, and the æstivation is imbricate. The ovule is solitary and pendulous.

3. *Ranunculeæ.*—These differ from the Anemoneæ in having both calyx and corolla, and in the solitary ovule being ascending.

In *Myosurus* there are only five stamens.

4. *Helleboreæ.*—The perianth is usually composed of both calyx and corolla, but the latter is sometimes suppressed. The carpels are generally fewer in number than the leaves of the perianth. The

fruit is composed of several follicles, except in *Nigella*, where it is a capsule, and *Actæa*, where it is a berry. There are two divisions in this tribe, one of which has regular flowers, as *Helleborus*, and the other irregular zygomorphic ones, as *Aconitum* and *Delphinium*.

5. *Pæoneæ*.—The perianth has both calyx and corolla; the fruit consists of two to five fleshy or leathery follicles, which are surrounded at the base by a conspicuous disc.

The order includes 30 genera and about 600 species. It is widespread in its distribution, but is scantily represented in the tropics, except on mountains.

The plants of this order generally abound in an acrid principle, which in some is even vesicant. This acridity is, however, very volatile, so that in most cases it is dissipated by drying, or by infusing them in boiling, or even sometimes in cold water; it varies also in different parts of the same plant, and even in the same parts at different seasons. Some plants contain in addition a narcotic principle; and when these principles are in excess, they are virulent poisons. Generally the plants of this order are to be regarded with suspicion, although some are simply bitter and tonic.

Order 2. DILLENIACEÆ.—The plants are usually trees or shrubs, sometimes climbing. They differ from those of *Ranunculaceæ* chiefly in having persistent sepals, and in their seeds being furnished with an aril. The stamens are sometimes united at their bases into one or more bundles.

Order 3. CALYCANTHACEÆ.—The plants are shrubs with opposite, entire, exstipulate leaves. The sepals and petals are arranged in several series, and the sporophylls are acyclic. The flowers differ from all others in the cohort by having perigynous stamens. The receptacle or thalamus is concave, and the carpels are attached separately to the sides of the cup which it forms.

Order 4. MAGNOLIACEÆ.—The plants are trees or shrubs with thick leaves, which are sometimes stipulate. The stipules in this case are large and envelop the bud, but fall off as the latter opens.

The perianth usually consists of one whorl of (three) sepals and two whorls of petals, but is sometimes pluriseriate. The sporophylls are acyclic, and the carpels are usually arranged spirally on a convex receptacle.

The order includes 9 genera and 70 species; it flourishes in tropical and eastern Asia and in North America; it is sparingly represented in tropical and extra-tropical South America, and in Australia and New Zealand. No plants of the order occur wild in Europe or Africa. Magnoliaceæ are distinguished from *Dilleniaceæ* by the absence of an aril from the seeds, and from *Anonaceæ* by the non-ruminated albumen.

Order 5. ANONACEÆ.—The plants of this order resemble those of the *Magnoliaceæ*, but differ in their seeds possessing a ruminated endosperm. The carpels are generally united and succulent, forming a kind of compound baccate fruit when ripe.

Order 6. MENISPERMACEÆ.—The plants of this order are chiefly twining plants, with herbaceous or woody stems. They are usually diœcious. The calyx, corolla, and andrœcium have generally two whorls each, and the carpels are usually three in number and are apocarpous. The fruit is drupaceous and the seeds are generally albuminous, the endosperm being ruminated. Sometimes the stamens are monadelphous.

Order 7. BERBERIDACEÆ.—The plants of this order are herbs or shrubs, sometimes climbing (*Lardizabaleæ*). The leaves are often spiny, and usually have no stipules. They may be simple or compound. The flowers are dimerous or trimerous, and have regularly alternating whorls of free sepals, petals, and stamens. The sepals are frequently in two whorls, but sometimes more. There are two whorls of petals, with a stamen opposite each. There is either a solitary carpel crowned by a sessile stigma which resembles a flattened disc, or there are three

FIG. 1035.

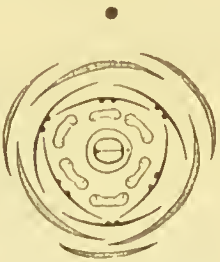


FIG. 1036.

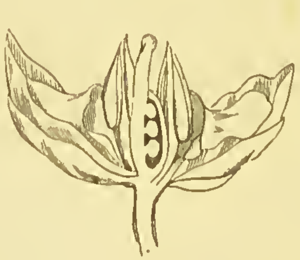


FIG. 1037.

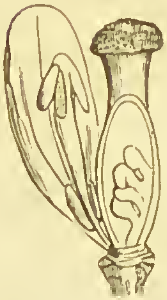


FIG. 1038.

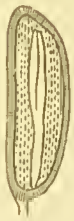


Fig. 1035. Diagram of the flower of the Barberry (*Berberis*).——*Fig.* 1036. Vertical section of the flower of *Epimedium*.——*Fig.* 1037. Vertical section of the ovary of *Berberis*.——*Fig.* 1038. Vertical section of the seed of *Berberis*, with the embryo in the axis surrounded by albumen.

carpels. The ovary contains several such ovules, and becomes a berry in fruit. The seeds are albuminous.

The order comprises the two tribes *Lardizabaleæ*, with unisexual flowers, the pistillate one having three carpels, and *Berbereæ*, in which the carpel is solitary. By some authors the Lardizabaleæ are included in the *Menispermaceæ*.

Berberis is the only British genus. It has two rows of sepals, petals, and stamens. The filaments of the stamens are sensitive to touch, and when thus stimulated they bend suddenly inwards towards the pistil. The anthers dehisce by recurved valves (*fig.* 1037). The flowers are in racemes and are borne on dwarf branches. In *Epimedium* the fruit is a capsule.

These plants are found in the temperate parts of Europe, America, and Asia, and are very common in the mountainous parts of the North of India. The order includes 20 genera and about 100 species.

They are generally acid, astringent, and bitter; but some are purgative. Their acid properties are due to the presence of oxalic acid.

Order 8. NYMPHÆACEÆ.—The plants of this order are aquatic in habit, having generally large floating entire leaves. If there are also submerged leaves they are very much dissected.

FIG. 1039.

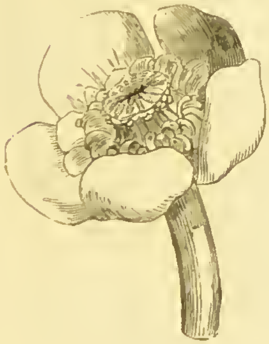


FIG. 1040.

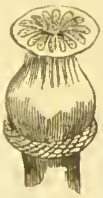


FIG. 1041.

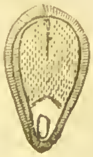


FIG. 1042.

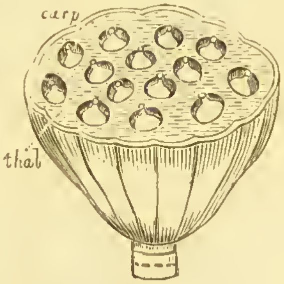


Fig. 1039. Flower of Yellow Water-lily (*Nuphar luteum*).—*Fig.* 1040. Ovary of *Nuphar* with numerous radiating stigmas.—*Fig.* 1041. Vertical section of the seed of *Nymphæa alba*, showing the embryo embedded in endosperm, outside which lies a mass of perisperm.—*Fig.* 1042. Pistil of *Nelumbium*. *thal.* Thalamus. *carp.* Carpels.

The flowers are usually acyclic, the petals passing gradually into the stamens. The arrangement of the stamens is typically hypogynous, but in some cases they are all, and in others the inner ones only, inserted at different heights on a torus, which encloses the carpels. The latter vary in number, usually from three to eight being present, and are either united into a syncarpous ovary or are embedded singly in cavities in a large receptacle which is raised above the level of the stamens (*fig.* 1042). The seeds are in most cases albuminous, containing usually both perisperm and endosperm. They are either situated on the sides of the dissepiments of the ovary, or are pendulous from the dorsal suture. In the apocarpous species they are pendulous from the apex of the carpel. They sometimes have an aril.

The order embraces the following tribes :—

1. *Cabombeæ.*—These plants have cyclic flowers and both submerged and floating leaves, and show the remarkable peculiarity of bearing their seeds attached to the *dorsal* suture of the carpels.

2. *Nelumboneæ.*—These plants have apocarpous pistils, the carpels being sunk in a large receptacle, in shape like an inverted cone (*fig.* 1042). The seeds are peculiar in being exalbuminous.

3. *Nymphæeæ.*—This tribe is represented by the White and Yellow Water-lilies. *Nymphæa alba*, the White Water-lily, has four

Fig. 1043.

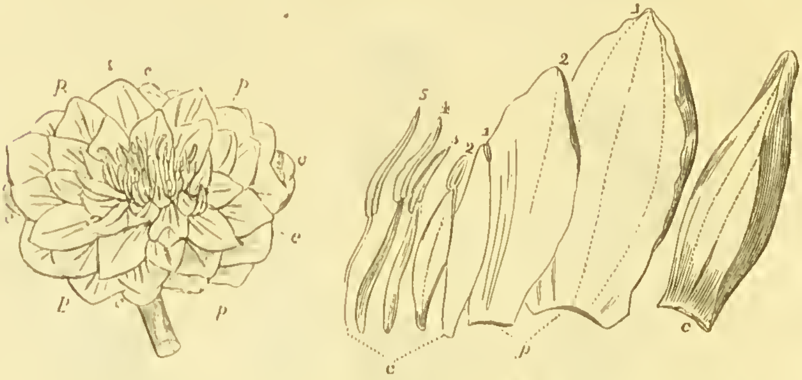


Fig. 1043. Flower of the White Water-lily (*Nymphæa alba*) reduced in size. After Jussien. *c, c, c, c.* The sepals. *p, p, p, p.* Petals. *e.* Stamens. The parts on the right show the gradual transition from the sepals, *c*, to the petals, *p*, and from these organs to the stamens, *e*. The stamens from 1 to 5 are gradually more distinctive.

green sepals, a great number of white petals arranged spirally, and very numerous stamens. There is a very gradual transition from the former to the latter, the blades of the petals becoming narrower by degrees, and anthers being developed at their apices. As the anther becomes more and more developed the blade of the petal becomes continuously narrower till it is recognisable as a staminal filament. The ovary is half inferior. *Nuphar*, the Yellow Water-lily, has five sepals and about thirteen petals, which are much smaller than those of *Nymphæa*, but are arranged similarly in a spiral with the stamens. The ovary is superior.

The plants of this order are chiefly found in quiet waters throughout the whole of the northern hemisphere, and more sparingly in the southern. There are 8 genera and 35 species.

This order is distinguished from the others of the Ranales by the seeds usually containing both endosperm and perisperm. The *Nymphææ* approach the *Papaveraceæ* in their placentation, but differ in the contents of the seed, and in their habit. The character of the seeds is almost the only distinction between *Cabomba* and the *Ranunculaceæ.*

These plants have bitter and astringent properties. The flowers are said to be narcotic.

Cohort 2.—*Parietales.*

The flowers have both calyx and corolla; the sepals and petals are free; the stamens may be definite or indefinite; the pistil is syncarpous; the ovary has nearly always parietal placentæ.

Order 1. SARRACENIACEÆ.—These plants are peculiar in having their leaves modified into curious urn-shaped bodies, or pitchers (*fig.* 1044), which contain a quantity of watery liquid. Insects falling or crawling into these are drowned and their bodies putrefy, the products of the decomposition being absorbed by the tissue of the leaf. The leaves are arranged in a kind of rosette, from the centre of which arise the flowers. The latter are generally actinomorphic, and sometimes have no petals. The stamens are spirally arranged, and generally number fifteen or more; the ovary is unilocular with parietal placentæ, or 3–5-chambered with placentæ axile.

FIG. 1044.

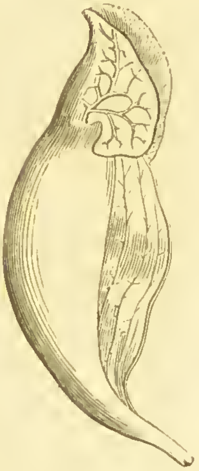


Fig. 1044. Pitcher of *Sarracenia.*

Order 2. PAPAVERACEÆ.—The plants of this order are herbaceous, and contain a milky or coloured latex. The flowers are generally regular; they have each two sepals, which are thrown off as the flower opens; two whorls of two petals each, which are crumbled in the bud; numerous stamens which are arranged in several whorls, and a syncarpous pistil composed of two or of many carpels. The fruit is a capsule, which dehisces by pores or by valves; it is unilocular, and the seeds are attached to placentas which project inwards from the lines of union of the carpels. The seeds are numerous, and contain besides a small embryo a quantity of oily endosperm.

Papaver, the Poppy, has a globose capsule crowned by a radiating stigma, the rays of which are above the placentas. The latter grow out towards the centre of the capsule and nearly meet in the centre. Each ray of the stigma is formed by the fusion of the edges of two carpels. The capsule opens by pores which are found under the radiating stigma in the angles between the rays. *Chelidonium* has only two carpels, which form an elongated capsule which dehisces by two valves that open from below (*fig.* 1047). It leaves the seeds attached to a kind of frame, composed of the edges of the carpels and the placentas which are developed upon them. The structure resembles the siliqua of the *Cruciferæ*, but has no replum or partition between the placentas. This structure is found, however, in *Glaucium*, the Horned Poppy, a genus which presents a transitional form to the Cruciferæ.

FIG. 1045.

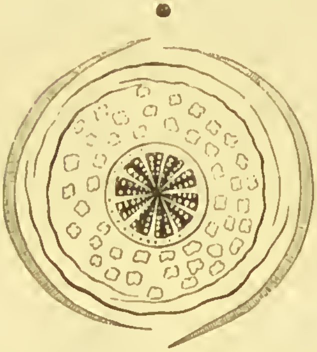


FIG. 1046.

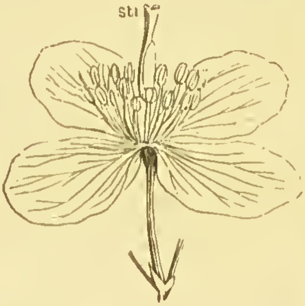


FIG. 1047.

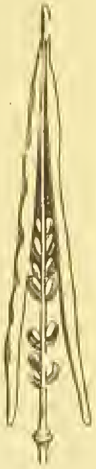


Fig. 1045. Diagram of the flower of the Poppy, with two sepals, four crumpled petals, numerous stamens, and a compound 1-celled ovary with several parietal placentas projecting into its interior so as to nearly divide it into several cells.——*Fig.* 1046. Flower of Celandine (*Chelidonium majus*). *sti.* Two stigmas on the apex of a lengthened or pod-like ovary. *Fig.* 1047. Siliqueform or pod-shaped capsule (*ceratium*) of Celandine.

The genus *Hypecoum* presents a similar transition to the *Fumariaceæ*. It has only four stamens.

Nearly two-thirds of the plants of this order are natives of Europe, and are mostly annuals. They are almost unknown in tropical regions, and are but sparingly distributed out of Europe in a wild condition. The order includes more than 130 species.

The plants of this order are in almost all cases characterised by well-marked narcotic properties. Some are acrid, while others are purgative. From a medicinal point of view, *Papaveraceæ* must be regarded as the most important order in the Vegetable Kingdom on account of its yielding Opium, undoubtedly the most valuable drug of the Materia Medica.

Order 3. FUMARIACEÆ.—By Bentham and Hooker this order is included in the *Papaveraceæ.* It differs from the description given of the latter in the symmetry of the flowers, and in the absence of the milky or coloured latex. The flowers are generally zygomorphic, the plane of symmetry being lateral and not antero-posterior. The flowers have two sepals which are caducous, two whorls of two petals, which alternate regularly with the sepals; of the outer whorl, one or both are gibbous at the base or prolonged into spurs (*fig.* 1048). The stamens are grouped into two phalanges or bundles of three each, of which the central one has a 4-celled anther, while those of the two lateral ones are only 2-celled, each being apparently half an anther. The two phalanges of stamens are opposite to the outer spurred petal or petals. The pistil is bicarpellate and develops into a fruit like that of *Chelidonium*, or into a nut with a partially succulent pericarp.

FIG. 1048.

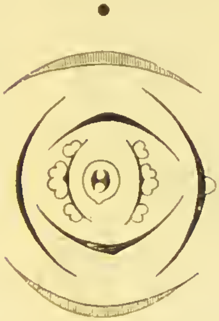


FIG. 1049.

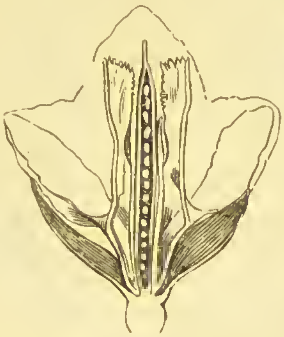


FIG. 1050.

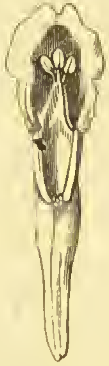


FIG. 1051.

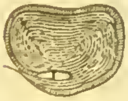


Fig. 1048. Diagram of the flower of *Corydalis*, with two sepals, four petals, in two whorls, six stamens in two bundles, and a 1-celled ovary with two parietal placentas.——*Fig.* 1049. Vertical section of the flower of *Hypecoum.*——*Fig.* 1050. Upper or posterior petal of *Corydalis*, spurred at the base and a bundle of three stamens.——*Fig.* 1051. Vertical section of the seed of *Fumaria.*

Dicentra has both outer petals spurred ; *Corydalis* and *Fumaria* have only one.

Order 4. CRUCIFERÆ.—The plants of this order are herbs, or very rarely shrubby plants. The leaves are simple, alternate, and exstipulate. The flowers are arranged in corymbs without bracts (*fig.* 1053), and are regular, but zygomorphic in more than one plane. There are four sepals in two whorls, of which the lateral, which are the most internal, are gibbous or almost pouched at their bases. A single whorl of four clawed petals alternates with the two whorls of sepals taken as if they formed but one whorl (*fig.* 1052). They are said to be placed *diagonally*. They are always symmetrical in shape, and as they are arranged they give the corolla the appearance of a Maltese cross, from which the name of the order is derived. The stamens are six in number; an outer whorl of two placed opposite to the gibbous sepals, and an inner whorl of four whose filaments are usually rather longer than those of the outer whorl. These four stamens are arranged in two pairs, each pair being opposite to one of the outer sepals. This arrangement has received the name of *tetradynamous*. There are two carpels which are united all the way up. At each line of union there is a well-marked placenta, and a false dissepiment or partition, which is really an outgrowth from the two placentas, divides the ovary into two loculi. The stigma is capitate and sessile. The ovules are borne upon the two parietal placentas and are curved. The corymb of the inflorescence becomes a regular raceme as the fruit is formed. The latter is generally a siliqua or a silicula,

FIG. 1052.

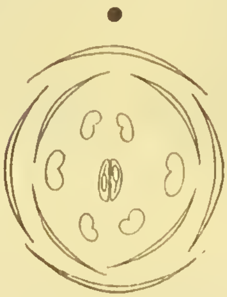


FIG. 1053.

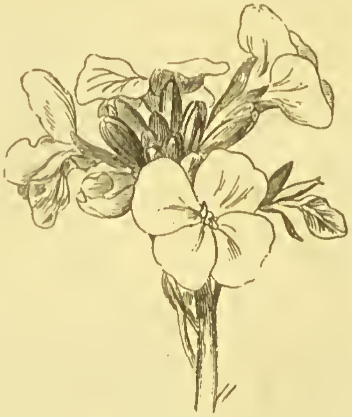


Fig 1052. Diagram of a Cruciferous flower.—*Fig.* 1053. Portion of the flowering branch of the Wallflower.

dehiscing by two valves which separate from the false dissepiment or *replum* from their bases upwards, leaving the seeds attached to the latter. The silicula may be compressed either laterally or dorsally. In some cases the fruit is a lomentum.

FIG. 1054.

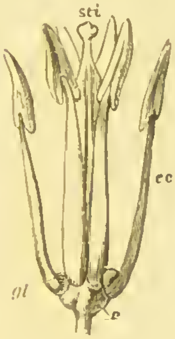


FIG. 1055.

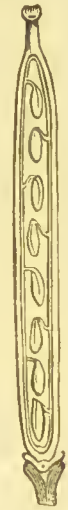


FIG. 1056.

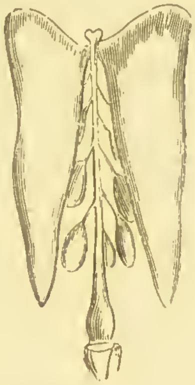


FIG. 1057.

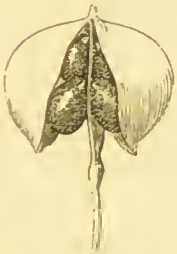


FIG. 1058.

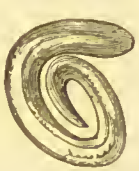


FIG. 1059.

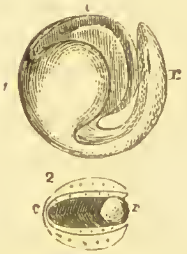


Fig. 1054. Sporophylls of the Wallflower (*Cheiranthus Cheiri*). *r.* Thalamus. *gl.* Glands. *ec.* Tetradynamous stamens. *sti.* Stigmas.——*Fig.* 1055. An unripe siliqua of the Wallflower, with one of the valves removed to show the replum and the stalked pendulous seeds.——*Fig.* 1056. The silicula of Shepherd's Purse (*Capsella Bursa-pastoris*) in the act of dehiscing, showing the stalked pendulous seeds.——*Fig.* 1057. Silicula of the Scurvy-grass (*Cochlearia officinalis*) in the act of dehiscing.——*Fig.* 1058. The embryo of *Bunias orientalis.*——*Fig.* 1059. The embryo of the Cabbage plant (*Brassica oleracea*). 1. Undivided. 2. Horizontal section. *r.* Radicle. *c.* Cotyledons.

The seeds are generally described as exalbuminous, but it has been stated by Guignard that a thin layer of endosperm generally persists.

In a few genera the fruits are indehiscent, and in some others they form a kind of lomentum, with transverse dissepiments between the seeds. A few exceptions to the exstipulate character of the leaves are known; in *Cochlearia* there are conspicuous scales occupying the position of the stipules, which are represented also by glands on the very young leaves of a few other genera. The most prominent features of the order are the cruciate corolla and the tetradynamous stamens. In a few genera this arrangement is apparently departed from, but this is due to some of the stamens being abortive. Thus *Senebiera* has only two median stamens, while *Nasturtium* and *Capsella* have four, and *Megacarpea* has numerous stamens. *Iberis* and *Teesdalia* have radiant flowers, and *Subularia* has perigynous stamens. Some flowers of the order are apetalous. In *Tetrapoma* there are four carpels.

The order has been divided into sub-orders according to the nature of the fruit, and also according to the mode in which the embryo is folded. The latter is the most natural arrangement.

The sub-orders founded on the nature of the fruit are as follows:—

Sub-order 1. *Siliquosæ.*—Fruit a siliqua, opening by valves longitudinally. Cheiranthus, *Linn.*; Brassica, *Linn.*

Sub-order 2. *Siliculosæ latiseptæ.*—Fruit a silicula opening by valves; the replum in its broader diameter. Cochlearia, *Linn.*

Sub-order 3. *Siliculosæ angustiseptæ.*—Fruit a silicula opening by valves; the replum in its narrower diameter. Capsella, *Mœnch*; Iberis, *Linn.*

Sub-order 4. *Nucumentaceæ.*—Fruit an indehiscent silicula; often 1-celled, owing to the absence of the replum. Isatis, *Linn.*

Sub-order 5. *Sepulatæ.*—The valves of the fruit opening longitudinally and bearing transverse septa in their interior. There are no examples among British plants.

Sub-order 6. *Lomentaceæ.*—Fruit a siliqua or silicula, dividing transversely into 1-seeded portions, the true siliqua sometimes barren the beak placed above it containing one or two seeds. Cakile, *Gaert.*; Raphanus, *Linn.*

This is essentially the same as the arrangement of Bentham and Hooker.

The sub-orders founded on the mode in which the embryo is folded are as follows:—

Sub-order 1. *Pleurorhizeæ* (○ =).—Cotyledons accumbent, flat; radicle lateral. Cheiranthus, *Linn.*; Arabis, *Linn.*

Sub-order 2. *Notorhizeæ* (○ ‖).—Cotyledons incumbent, flat; radicle dorsal. Hesperis, *Linn.*; Isatis, *Linn.*

Sub-order 3. *Orthoploceæ* (○ ≫). Cotyledons conduplicate, longitudinally folded in the middle; radicle dorsal, within the fold. Brassica, *Linn.*; Raphanus, *Linn.*

Sub-order 4. *Spirolobeæ* (○ ‖ ‖).—Cotyledons twice folded, linear, incumbent. Bunias, *Linn.* There are no examples among British plants.

Sub-order 5. *Diplecolobeæ* (○ ‖ ‖ ‖). Cotyledons thrice folded, linear, incumbent. Senebiera, *DC.*; Subularia, *Linn.*

The plants of this order chiefly inhabit temperate climates. A large number are also found in the frigid zone, and a few in tropical regions, chiefly on mountains. The order includes about 1,600 species.

This order is generally characterised by antiscorbutic and pungent properties, frequently combined with acridity; it is one of the most natural in the Vegetable Kingdom, and does not include a single poisonous plant. The seeds frequently contain a fixed oil. Many of our commonest culinary vegetables are derived from this order. *Brassica oleracea* is the Cabbage; *B. Botrytis* has connate fleshy peduncles and abortive flowers; its varieties form the Broccoli and the Cauliflower; *B. gemmifera*, with numerous lateral leaf-buds, is known as Brussels Sprouts. The Kohl-rabi (*B. caulorapa*) has a large swelling at the base of the stem, just above the ground; the Turnip (*B. campestris* var. *Rapa*) has a similarly swollen tap-root. Colza and Mustard are both species of this genus.

FIG. 1060.

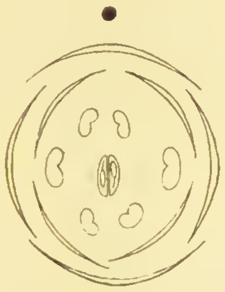


FIG. 1061.

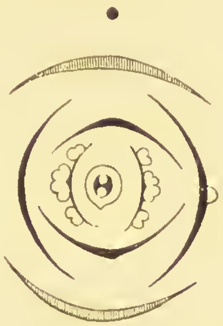


Fig. 1060. Diagram of a Cruciferous flower.——*Fig.* 1061. Diagram of the flower of *Corydalis*, with two sepals, four petals, in two whorls, six stamens in two bundles, and a 1-celled ovary with two parietal placentas.

The flowers of the Cruciferæ and the Fumariaceæ, though at first sight very different, have much in common, being apparently arranged upon the same plan. The diagrams of typical flowers of the two orders are shown in *figs.* 1060 and 1061. In both the perianth is composed of three whorls; in Cruciferæ the two outer being considered sepals, in Fumariaceæ the two inner being regarded as petals. In Cruciferæ the inner whorl is of four petals placed diagonally; in Fumariaceæ of two petals placed antero-posteriorly. In Cruciferæ the stamens are tetradynamous; in Fumariaceæ they are in two bundles, each comprising three anthers, of which the middle one is 4-celled and the outer ones each 2-celled.

There have been two views taken of the structure of the flower in the Cruciferæ, which represent it as on the tetramerous and dimerous types respectively.

The view of the observers who adopted the first theory was that the floral leaves were arranged in whorls of four. The stamens they accounted for by saying there were originally four staminal protuberances, of which the anterior and posterior ones were by chorisis made into four. The ovary being bicarpellate presented a further difficulty; but they quoted as the typical genus of the order, *Tetrapoma*, the diagram of whose flower is shown in *fig.* 1062. This view was based on the researches of Payer, as published in his 'Organogénie de la fleur.'

Fig. 1062.

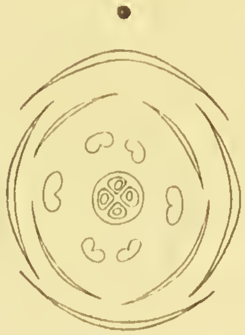


Fig. 1063.

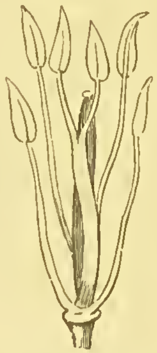


Fig. 1062. Floral diagram of *Tetrapoma*, a Cruciferous flower with four carpels.——*Fig.* 1063. Flower of a species of *Streptanthus*, with the floral envelopes removed, showing a branched stamen in place of the two anterior stamens. From Gray.

Other observers who held the tetramerous view regarded the stamens differently. They considered that the four stamens did not arise from chorisis, but that they were always separate, and that there were originally six protuberances. They held that the stamens were in two whorls of four each, two stamens of the outer whorl being suppressed. Against this view must be urged the consideration that the inner (longest) stamens are not properly alternate with those of the outer whorl so constructed, being nearer the longitudinal axis of the flower, and not opposite the centres of the petals. Moreover, each of these two pairs of stamens is occasionally found represented by a single filament which is branched near its apex and bears two anthers (*fig.* 1063). These observers also considered that the ovary of *Tetrapoma* was the true type of the order, and that in all other genera two carpels were suppressed. They rejected Payer's views as to the chorisis of the inner stamens.

The floral diagrams of the two views of the tetramerous type are shown in *figs.* 1064 and 1065.

The dimerous view was suggested by Eichler in the course of his studies on the Brazilian flora. He found that there were only four original staminal protuberances, two of which subsequently divided.

FIG. 1064.

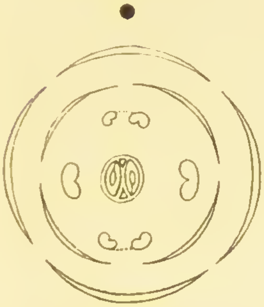


FIG. 1065.

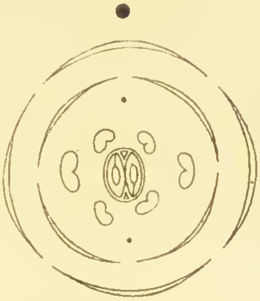


FIG. 1066.

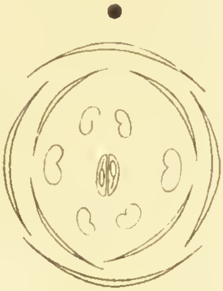


Fig. 1064. Diagram of a Cruciferous flower based upon the theory of tetramerous symmetry with one whorl of stamens, the anterior and the posterior having undergone chorisis.——*Fig.* 1065. Diagram of a Cruciferous flower based upon the theory of tetramerous symmetry with two whorls of stamens, the anterior and posterior ones of the outer whorl being suppressed. Their supposed places are indicated by dots.——*Fig.* 1066. Diagram of a Cruciferous flower based upon the theory of dimerous symmetry.

He also observed that the parts of the flower arose in a definite order: (1) two antero-posterior sepals; (2) two inner lateral sepals; (3) four protuberances for the petals in positions alternating with the four sepaline protuberances as if the latter had formed a single whorl; (4) two lateral prominences for the outer stamens; (5) two antero-posterior protuberances afterwards splitting, which formed the antero-posterior stamens, which are never opposite to the petals, and hence do not fall in with the tetramerous hypothesis, being out of position. He therefore proposed two as the type of arrangement, and did not regard Tetrapoma as showing the latter. On this view we have, as in *fig.* 1066, two outer sepals antero-posterior, two inner sepals lateral, alternating with them, four petals which are equivalent to a whorl of two, each of which has undergone either chorisis or doubling, and which were placed antero-posteriorly.

Then two outer stamens, alternating with these two hypothetical petals, and therefore opposite to the inner sepals; then two inner stamens, opposite to the outer sepals, and themselves doubled. They alternate with the outer stamens. Finally two carpels alternate with these. Eichler has thus settled the question of the stamens, finding as he has done that two protuberances split to give rise to the four inner stamens. A common monstrous condition of the Cruciferous flower, especially that of *Cheiranthus* and of *Streptanthus*, bears out this view, for we often find the filaments in such coherent for a considerable part of their length (*fig.* 1063). In *Senebiera*, again, the long stamens are only two in number, the protuberance not having divided, while the lateral ones are altogether abortive.

Arguments in favour of Eichler's view of the development of the petals may be brought forward based on symmetry. From the mature flower, as we now see it, we could gather nothing as to whether the petals that have undergone chorisis were situated antero-posteriorly or laterally. In the latter case the symmetry of the flower would be opposed to the regular alternation of parts which we find in all regular flowers. In the former it would fall in with it exactly. In the genus *Hypecoum*, of the allied order *Papaveraceæ* (*fig.* 1067), which throws light on the question of the development of the stamens in the group under discussion, we find the two leaves of the third whorl of the perianth are 3-lobed, and are situated antero-posteriorly. If the middle lobe of these leaves or petals were suppressed, and the groove between the outer lobes extended to the base, we should have four petals exactly in the position of the four petals of Cruciferæ. The two Natural Orders being very closely allied in other structural respects, leaves it at any rate possible that the petals in Cruciferæ have so originated. The chorisis of the two staminal protuberances shows that such division actually takes place in the flower.

Referring to the diagram of the typical flower of Fumariaceæ (*figs.* 1048, 1068) we find the stamens apparently in two bundles, or phalanges, on the same level, each being made up of a complete central anther and two lateral half-anthers. Two interpretations have been given of this. The first is due to De Candolle and Lindley. It assumes that the stamens were originally four in two whorls, as is now seen in the genus Hypecoum (*fig.* 1067); that those of the inner whorl became split, and through displacement the halves of each became forced outwards until they were on the same level as the outer whorl; that the two halves, each bearing a single anther lobe, became coherent with the stamens of the outer whorl, and consequently separated as widely as possible from each other. Thus the appearance of the stamens in Fumaria comes to be as figured in the diagram (*fig.* 1068). On this theory the structure of Hypecoum shows the type of the order, and that of Fumaria is a modification of it. This view is very similar to the theory of Payer as to the stamens in Cruciferæ, and agrees with the observations of Eichler; for if we stop at the chorisis of the stamen, and instead of supposing the resulting lobes to separate from each other and unite with the lateral stamens, we assume that each half becomes of the form and dimensions of the original one, we have the tetradynamous structure of *fig.* 1066. The second theory was advanced by Eichler, and is nearly the opposite of the first as regards the relation of Hypecoum to Fumaria. It starts with noticing that in Hypecoum the petals are 3-lobed, the central lobe being much the largest. So in Fumaria the staminal bundle may be taken to represent a 3-lobed leaf, with the central lobe largest. He therefore suggested that the 3-lobed

Fig. 1067.

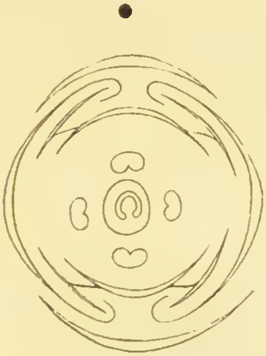


Fig. 1068.

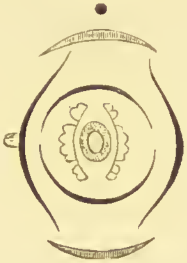


Fig. 1067. Floral diagram of *Hypecoum.*——*Fig.* 1068. Floral diagram of *Fumaria.*

leaf is the type of the floral leaf, and that this type is preserved in the petals of Hypecoum and the stamens of Fumaria. It resolves itself thus into a question of branching of the floral protuberances, which, as we shall see, is not at all uncommon in other flowers. The structure of the andrœcium in Hypecoum presents a difficulty; but after a study of the distribution of the vascular bundles of the stamens, there being two such bundles in the stamens which are before the inner petals, Eichler has suggested that there is no true inner whorl of stamens any more than there is in Fumaria, and that those which take their places before the inner petals are made up of the single lobes chorised from the lateral stamens, displaced and coherent. Thus the andrœcium of Hypecoum is derived from the type of that of Fumaria. We must assume that, as in Cruciferæ, there should be two whorls of stamens in Fumariaceæ, as the carpels are opposite to the staminal phalanges.

Order 5. CAPPARIDACEÆ.—This order shows a close relationship with the *Cruciferæ*, but the stamens are not tetradynamous. There are typically four stamens, which are in some cases undivided; in others both the median ones are divided into two each, in others only one of them, and in others again all four are divided, so that the stamens become indefinite. The pistil is bicarpellary and syncarpous, but there is no replum, and the ovary is unilocular. More than two carpels may occur. The floral axis within the sepals is peculiar in that the internode between the stamens and petals is often elongated, as is that between the stamens and pistil, so that the latter appears to be seated on a long stalk, known as a *gynophore*. The habit of the plants is usually arborescent or shrubby.

FIG. 1069.

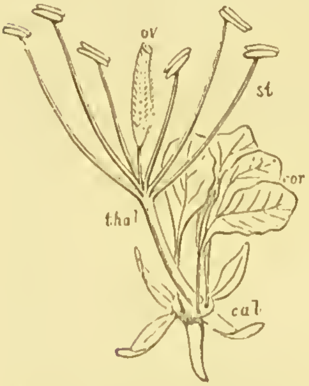


Fig. 1069. Flower of *Gynandropsis* (*Capparidaceæ*). *cal.* Calyx. *cor.* Corolla. *thal.* Gynophore, supporting the stamens, *st*, and the ovary, *ov*.

Order 6. CISTACEÆ.—This order comprises a number of shrubs or herbs with usually regular pentamerous flowers, arranged in scorpioid cymes. The five sepals appear in two ranks (*fig.* 1070), two smaller standing outside three larger ones; the petals are very fugacious; the stamens are numerous in consequence of branching or multiplication. The pistil is syncarpous, and the placentation is in some cases parietal and

FIG. 1070.

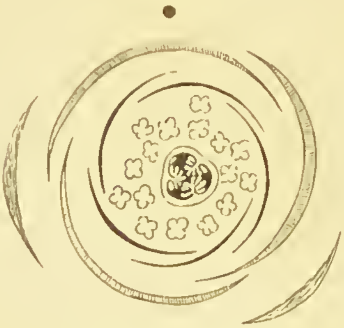


FIG. 1071.

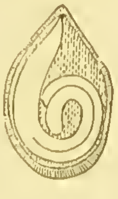


Fig. 1070. Diagram of the flower of a species of *Helianthemum*.——*Fig.* 1071. Section of the seed of a species of *Cistus*, the pointed end being its apex in others axile. The ovules differ from those of most of the cohort in being orthotropous. The seeds are albuminous and the embryo is curved (*fig.* 1071). The order is much like *Papaveraceæ*, from which it can be distinguished by the sepals, which are five in number and not caducous.

Order 7. RESEDACEÆ.—The plants of this order are herbs or small shrubs with alternate leaves, each with small gland-like stipules. The flowers are zygomorphic owing to the development of the posterior side of the floral axis bearing the petals, which forms a large hypogynous disc. The petals are much divided for some distance down, appearing fringed. The stamens are indefinite; the ovary is tricarpellary, 1-celled with parietal placentas, and is open at the apex. The seeds are usually numerous, and are reniform and exalbuminous. The embryo is curved.

Order 8. VIOLACEÆ.—The plants of this order show a good deal of variety in habit. The British forms are herbaceous, but shrubs and lianes occur in the tropics. The leaves are simple and bear large lobed stipules. *Viola* is the only British genus. Its flowers are usually zygomorphic (*fig.* 1072); the sepals are five, and are prolonged backwards beyond their point of insertion; the petals are five, of which the anterior is the largest and bears a long spur into which honey is secreted by nectaries placed on two long spurs carried by the two anterior stamens. The anthers are loosely connected together and form a kind of box or chamber round the ovary and style. They are

FIG. 1072.

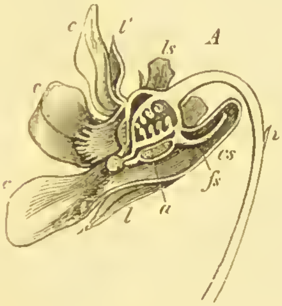


FIG. 1073.

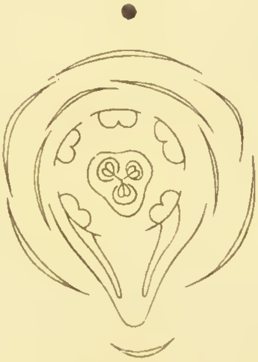


Fig. 1072. Flower of *Viola*, cut longitudinally. *a*. Stamen bearing nectariferous spur, *fs*, which passes backwards into the spur of the petal, *cs*. *c*. Petals. *l*. Sepals. After Sachs.——*Fig.* 1073. Floral diagram of *Viola*.

curiously crested, the filaments being prolonged beyond them. The pistil is tricarpellary, with parietal placentas; the style is club-like, and bears the stigma in a little groove or chamber on the anterior side; this chamber is partially protected by a kind of valve situated immediately below it. The fruit is a capsule dehiscing loculicidally, so that three valves fall backwards, each with a row of seeds along its central line.

The flower is pollinated by bees, which alight on the large petal and insert their proboscides into its spur. Passing the anthers and disturbing them, a shower of pollen falls upon the proboscis. As it is withdrawn the pollen is prevented by the valve from reaching the stigma within its chamber. A proboscis bearing pollen can deposit the latter in the stigmatic chamber as it is inserted into the flower.

Many species of Viola produce also cleistogamic flowers, which secure the production of seeds in the absence of insect visitors.

The tribe *Sauvagesieæ*, which was formerly held to be a distinct order, differs from the type described in having staminodes, which may be only five or may be numerous. The anthers are not crested, and the dehiscence of the capsule is septicidal.

Order 9. CANELLACEÆ.—A small order placed by some authors in *Clusiaceæ*, from which, however, it can be distinguished by its alternate leaves, its albuminous seeds, the absence of a disc, and the presence of a style.

Order 10. BIXACEÆ.—This order is closely allied to the *Cistaceæ*, from which it differs chiefly by having anatropous ovules. The plants are arborescent in habit, and have simple, often stipulate leaves, which in some cases bear oil glands or reservoirs.

Cohort 3.—*Polygales.*

The flowers have both calyx and corolla; the stamens are not indefinite; the pistil is syncarpous, and the ovary is usually 2—3-celled with axile placentation. In a few cases parietal placentation occurs.

Order 1. PITTOSPORACEÆ.—This is a small order chiefly of Australian plants, and is by some writers held to be closely allied to the *Saxifragaceæ*. There are five sepals, five petals, and five stamens regularly alternating with each other, and two to five carpels which form a syncarpous ovary, either 1- or 2-celled. The fruit of some species is a capsule, that of others is a berry.

Order 2. POLYGALACEÆ.—The plants of this order are herbs or shrubs, usually with spirally arranged leaves which are exstipulate. The tropical forms include some lianes. The flowers are borne in racemes (*fig.* 1074) or spikes, and are zygomorphic in the median plane. There are five sepals, of which the two lateral ones are very conspicuous, forming a pair of petaloid 'wings.' There are generally only three petals, the two antero-lateral ones being suppressed. Of these three, the anterior is carinate or boat-shaped and frequently fimbriated or crested.

FIG. 1074.

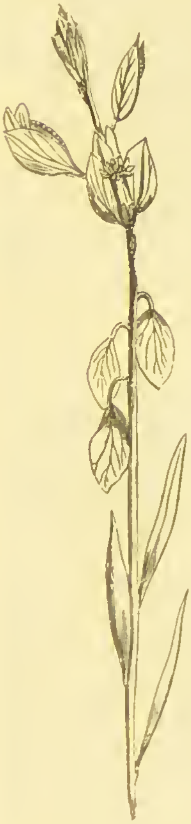


FIG. 1075.

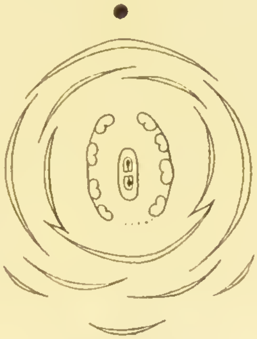


FIG. 1076.

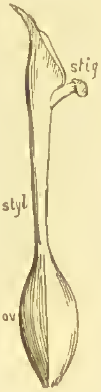
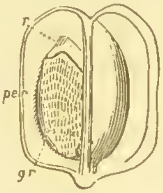


FIG. 1077.



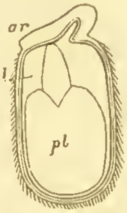


FIG. 1078.

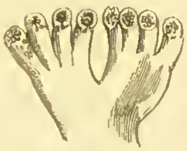


FIG. 1079.

Fig. 1074. A portion of the stem of the common Milkwort (*Polygala vulgaris*), with simple alternate exstipulate leaves, and irregular flowers.——*Fig.* 1075. Diagram of the flower of the same.——*Fig.* 1076. Gynœcium of the same. *ov.* Ovary. *styl.* Style. *stig.* Stigma.——*Fig.* 1077. Fruit with one cell opened. *per.* Pericarp. *gr.* seed *r.* Caruncula.——*Fig.* 1078. Section of seed. *te.* Testa. *ar.* Caruncula. *al.* Albumen. *pl.* Embryo.——*Fig.* 1079. Andrœcium of the same, with 1-celled anthers dehiscing at their apex

There is sometimes a slight union of the petals at their bases. Occasionally all five petals are developed. The stamens are eight in number, two being suppressed; they form a tube which is open on the posterior side and which is slightly adherent to the anterior petal or keel. The staminal tube is somewhat cleft on the anterior side, forming two groups of anthers. The anthers open by pores at their apices (*fig.* 1079). There are only two carpels, which form a 2-celled ovary, each cell containing a single pendulous ovule. The style is sometimes hooded at the apex, and the stigma protrudes laterally. The fruit is a loculicidal capsule, or in some species a nut. The seeds are pendulous and albuminous, and bear a caruncle.

Polygala, the Milkwort, is the only English genus.

The greater part of the plants of this order are bitter and acrid, and their roots milky; hence they are frequently tonic, stimulant, and febrifugal. Some are emetic, purgative, diuretic, sudorific, or expectorant. The roots of the different species of *Krameria* are very astringent from the presence of tannic acid; they are commonly known under the name of *Rhatany roots*. A few species have edible fruits, and others abound in a saponaceous principle.

Order 3. TREMANDRACEÆ.—This is a small order of Australian plants, which only differ from *Polygalaceæ* in having regular flowers.

Order 4. VOCHYSIACEÆ.—A small and unimportant order of American plants. They are trees or shrubs, in most cases having opposite leaves. They have irregular flowers, usually with only one stamen; there may be one to four staminodes.

Cohort 4.—*Caryophyllales.*

The flowers are usually regular; the perianth in most cases has both calyx and corolla. The pistil is ultimately 1-celled with free-central placentation. Occasionally parietal placentation occurs, but this is rare. The seeds sometimes have perisperm.

Order 1. CARYOPHYLLACEÆ.—The plants of this order are all herbaceous. They have stems which are tumid or swollen at the nodes, and bear opposite entire leaves which are usually exstipulate. If stipules occur they are small and membranous. The inflorescence is always cymose, and frequently takes the form of a dichasium whose ultimate branches become scorpioid. The flowers are regular, and for the most part contain both stamens and carpels. In a few species they are diœcious. The flowers are pentamerous or tetramerous, but there are usually two whorls of stamens, in which case they are obdiplostemonous, the outer whorl of stamens being opposite the petals. This is sometimes not easy to see, the stamens apparently forming a single whorl. The petals are unguiculate, and the claw is bent at a right angle to the limb. In a few species the flowers have no petals. The ovary is superior and syncarpous, and may consist of from two to five carpels. The styles are free. The placentation in the mature flower is free central; there are often traces of dissepiments at the apex of the ovary which point to the free-central condition as the result of abortion or suppression of the dissepiments of an originally axile placentation. The fruit is in some cases a nut, but more generally a membranous capsule, which opens at the apex, each carpel giving rise to one or to two valves, or teeth. The seeds have a curved embryo (*fig.* 1084).

FIG. 1080.

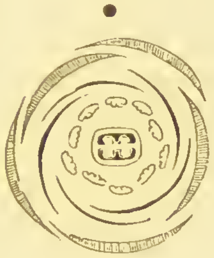


FIG. 1081.

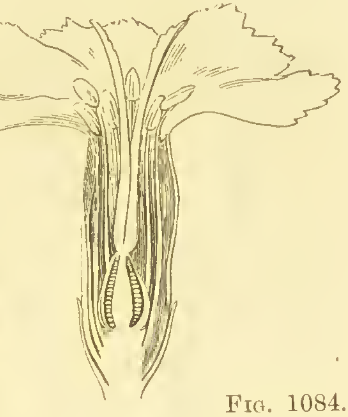


FIG. 1083.

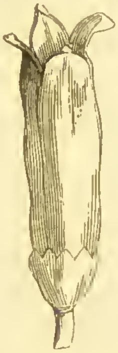


FIG. 1082.

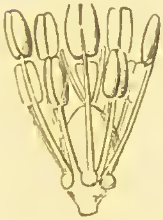


FIG. 1084.

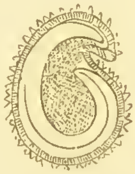


Fig. 1080. Diagram of the flower of a species of *Dianthus*.——*Fig.* 1081. Vertical section of the flower of the same.——*Fig.* 1082. Sporophylls of a species of *Stellaria*.——*Fig.* 1083. Capsule of a species of *Dianthus*, dehiscing partially in a valvular manner so as to form four teeth at the apex.——*Fig.* 1084. Vertical section of the seed of Chickweed (*Stellaria media*).

The order is divided into the following tribes:—

1. *Alsineæ.*—The sepals are distinct and opposite to the stamens when the latter are isomerous with them. The petals are often deeply cleft. The number of stamens varies a good deal, several often being abortive. There are usually no stipules, and the corolla is sometimes absent.

2. *Sileneæ.* The calyx is gamosepalous, and the corolla is always present. Each petal bears a ligular outgrowth at the junction of claw and limb. The stamens are occasionally slightly connate with

each other at their bases; there are no stipules. The internode of the floral axis between the calyx and corolla is sometimes elongated, forming a short gynophore, as in *Lychnis*. Diœcious forms occur in this group (*Lychnis dioica*). *Cucubalus* has a berry-like indehiscent fruit.

3. *Polycarpeæ*.—In this group the leaves have scarious stipules; the sepals are free, and the inner whorl of stamens is suppressed.

4. *Mollugineæ*.—The sepals are sometimes slightly united at their bases; the outer whorl of stamens is not always present. There are no stipules, and the leaves are often fleshy. Bentham and Hooker include this tribe in *Mesembryanthaceæ*.

FIG. 1085.

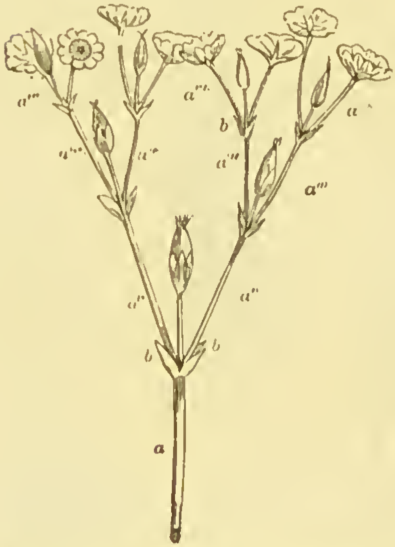


Fig. 1085. Dichasial cyme or dichasium of *Cerastium*. *a*, *a''*, *a'''*, *a''''*, the successive axes. *b*, Bracts.

5. *Paronychieæ*.—This group was formerly held to be a distinct Natural Order with affinities with the *Chenopodiaceæ*. By some authors it is placed among the Calycifloræ, as the flower is somewhat perigynous. It seems to form a link between the Curvembryeæ and the Caryophyllales. It consists of small greenish plants with generally opposite leaves, and in some cases with membranous stipules. The corolla is seldom present. The number of stamens varies, the inner whorl sometimes being suppressed. Bentham and Hooker place this group among the Monochlamydeæ under the name *Illecebraceæ*.

Order 2. FRANKENIACEÆ.—This is a small order of herbs or shrubs, allied to the *Caryophyllaceæ* by their nodose stems and opposite exstipulate leaves. They are often placed near the *Violaceæ*, as they have parietal placentation. They chiefly occur in the Mediterranean region.

Order 3. TAMARICACEÆ.—These are shrubby plants with small whip-like branches bearing small sessile leaves adpressed to them. The flowers are usually pentamerous, the stamens being either five or ten. The pistil has three carpels, and the ovary is 1-celled with parietal placentas. The seeds are woolly.

Order 4. PORTULACACEÆ.—The plants of this order, like the tribe *Paronychieæ*, show considerable affinities with the *Chenopodiaceæ*. They are succulent herbs or shrubs with entire exstipulate leaves.

There are usually two connate sepals enclosing five petals; the stamens vary in number, but are generally five, and are then opposite the petals. Some species have a second whorl, and in some, branching (or *dédoublement*) of the stamens occurs. The pistil is usually composed of three carpels, which unite to form a 1-celled ovary with a free-central placenta.

These plants are natives of waste dry places in various parts of the world, but chiefly at the Cape of Good Hope and in South America. There are about 190 species.

The fleshy root of *Claytonia tuberosa* is edible. *Portulaca oleracea* has been used from the earliest times as a pot-herb, and in salads. It possesses cooling and antiscorbutic properties. Many of the plants have large showy flowers.

Cohort 5.—*Guttiferales.*

The flowers are generally actinomorphic and eucyclic; the calyx is usually polysepalous, the stamens generally numerous; the pistil is syncarpous; the ovary may be 1-celled or many-celled; the placentation is usually axile, and the seeds are without albumen.

Order 1. Elatinaceæ. These are small aquatic plants with hollow creeping stems, and opposite or whorled leaves with interpetiolar membranous stipules. The flowers are small, and are solitary in the axils of ordinary foliage leaves. They are 3—5-merous and diplostemonous. The fruit is a capsule with axile placentation.

Order 2. Hypericaceæ.—The plants of this order are herbs, shrubs, or trees, with simple entire leaves, either opposite or whorled. The leaves have no stipules. The inflorescence is

Fig. 1086.

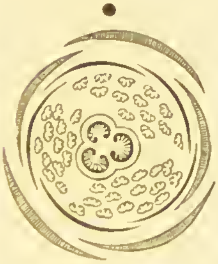


Fig. 1087.

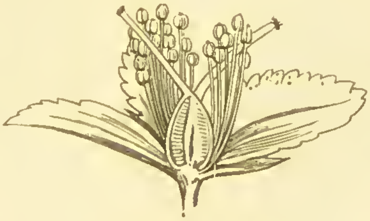


Fig. 1088.

Fig. 1086. Diagram of the flower of a species of St. John's Wort (*Hypericum*).——*Fig.* 1087. Vertical section of the flower of the same.——*Fig.* 1088. Vertical section of the seed.

cymose. The sepals and petals are five each, the latter usually bright yellow in colour; the stamens are numerous, but arise from either three or five original protuberances (*figs.* 1086, 1087, 1089). They are spoken of as triadelphous or pentadelphous. Each bundle is due to branching of one original staminal outgrowth. When the bundles are equal in number to the petals, they arise opposite to them. Frequently a whorl of staminodes occurs between the petals and the stamens, alternating with them. The pistil consists of three or five carpels, syncarpous with axile or parietal placentation. The fruit is a capsule or a berry. The staminal bundles do not always correspond in number with the carpels.

FIG. 1089.

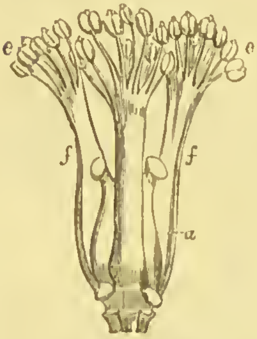


Fig. 1089. Triadelphous stamens of a species of *Hypericum.*

The order is characterised also by the presence of oil or resin channels or passages in the stems, and in the tissues of the ovaries. There are numerous globular reservoirs of etherial oil scattered in the substance of the leaves, which have the appearance of pellucid dots when viewed by transmitted light. Numerous black or dark purple glands are also present upon the leaves and petals. Their function is unknown.

The plants are generally distributed over the globe, inhabiting both temperate and hot regions, and almost all varieties of soil. There are about 280 species.

FIG. 1090.

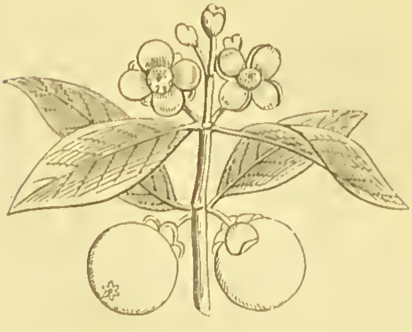


Fig. 1090. Flowering stem and fruit of the Mangosteen plant (*Garcinia Mangostana*).

These plants abound usually in a resinous yellow juice, which is frequently purgative, as in *Vismia guianensis* and *V. micrantha.* Other plants of the order, as *Hypericum perforatum* and *H. Androsæmum*, have tonic and astringent properties, and *Cratoxylon Hornschuchii* is slightly astringent and diuretic.

Order 3.—GUTTIFERÆ or CLUSIACEÆ.—This is a small order closely allied to the last, but often having diclinous flowers. Like the Hypericaceæ, they yield a resinous secretion.

They are exclusively tropical, and occur especially in moist situations. The larger proportion are natives of South America, but a few are found in Madagascar and the African continent.

Order 4. TERNSTRŒMIACEÆ.—The plants of this order bear flowers which are singular in that the bracteoles pass gradually over into the sepals, and these in turn into the petals, the whole collection being spirally arranged. The stamens are numerous in many whorls, and tend to become polyadelphous. The plants are trees or shrubs with entire coriaceous exstipulate leaves.

The most widely known plants of this order are *Camellia japonica* cultivated for its flowers, and *Thea chinensis*, the dried leaves of which constitute tea.

Order 5. DIPTEROCARPACEÆ.—This is an order of trees and shrubs found in tropical Asia. The fruits are surrounded by the enlarged persistent calyx which gives them the appearance of being winged. The leaves bear large convolute deciduous stipules. The flower is somewhat like that of the *Hypericaceæ*, but the grouping of the stamens is less distinct.

Order 6. CHLÆNACEÆ.—The plants of this order are trees or shrubs, which are readily distinguished among the Thalamifloræ by their alternate simple stipulate leaves and their involucrate flowers. The latter are sometimes solitary, at others two together, the involucre then surrounding both. The stamens are monadelphous; the fruit is a capsule, with usually axile placentation. The seeds are albuminous.

Cohort 6.—*Malvales.*

The flowers are usually actinomorphic and pentamerous; the calyx is often gamosepalous. The æstivation of the sepals is valvate, that of the corolla usually contorted. The stamens are typically in two whorls, often obdiplostemonous. In some cases they are united into a column, when the typical number is very greatly increased owing to branching. The carpels are usually five, but in some cases indefinite; the fruit in the latter case is a schizocarp, in the former a capsule.

Order 1. MALVACEÆ.—The plants of this order are herbs, shrubs, or trees, with alternate palmatinerved leaves with stipules; the flowers are regular. There are five sepals, which are valvate in the bud, and below them there is generally an epicalyx consisting in some cases of three, in others of several, leaves (*figs* 1096, 1097). The corolla has five petals, which are twisted in the bud and are slightly coherent at the base, where they are united to the staminal tube. There are numerous stamens united into a central column, which is hollow and encloses the styles. The stamens originate in five original protuberances, the large number being due to branching of these. The anthers are reniform and bilocular. The carpels are 3—∞, and are more or less completely united, forming either a capsular fruit or a schizocarp, which separates into a number of cocci, each containing one seed (*fig.* 1094). The endosperm is scanty and contains a quantity of mucilage; the embryo is curved, and the cotyledons are much twisted.

Fig. 1091.

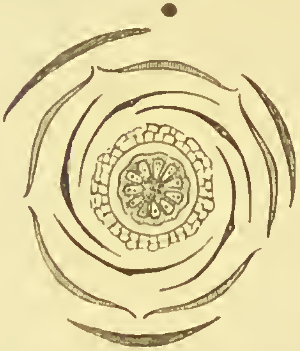


Fig. 1092.

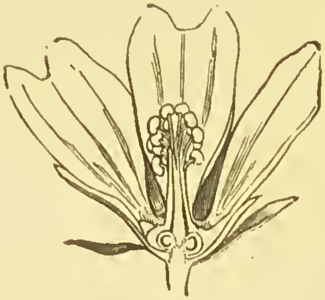


Fig. 1093.

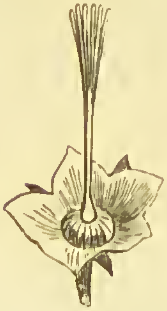


Fig. 1094.

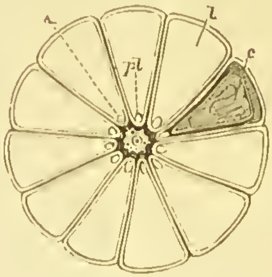


Fig. 1091. Diagram of the flower of a species of *Malva*. The three external lines represent bracts, which together form an epicalyx or involucre.——*Fig.* 1092. Vertical section of the flower of a Mallow.——*Fig.* 1093. Pistil of the same surrounded by the inferior calyx and involucre.——*Fig.* 1094. Horizontal section of the fruit of *Malva sylvestris*. A. Axis. *pl.* Placenta. *l.* An empty cell. *c.* Embryo with twisted cotyledons.

There is a good deal of variety in the structure of the flower. In *Malva* there is only one whorl of stamens present, which are arranged as described above. The five original protuberances arise opposite to the petals. The carpels are numerous, but arise more or less distinctly opposite to the petals. In *Hibiscus* the staminal tube terminates in five teeth, which form a kind of coronal appendage. The teeth of the tube are opposite to the sepals, as are also the carpels. In *Sidalcea* there are two whorls of stamens, of which the outer consists of five more or less distinct phalanges, which are membranous and situated opposite the petals, while the inner ones are columnar, as in Malva. In *Pavonia* and *Malvaviscus* the carpels are five and are antipetalous, the stamens being as in Malva.

An hypothesis has been advanced by Braun to explain the structure of Malva, which is that an outer whorl of antisepalous stamens has been suppressed. The carpels being opposite to the petals and to the original staminal protuberances, require for symmetry the supposition that there is a suppression of a third staminal whorl between them and the column of stamens. This would make the typical structure triplostemonous. The structure of *Hibiscus* favours this theory, as the teeth of the staminal tube correspond in position with this whorl, being antisepalous. If this be so, then the carpels have undergone a shifting in this flower, as is the case in the obdiplostemonous *Geraniaceæ*. In *Sidalcea* this inner whorl of stamens is represented by the column, and the stamens of Malva by the five membranous staminal phalanges. In both these genera Braun's hypothesis is wanted to account for the position of the outer whorl of stamens, which is antipetalous. In *Pavonia* and *Malvaviscus* the flower would be symmetrical if both suppressed whorls were supplied.

Fig. 1095.

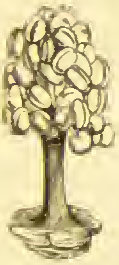


Fig. 1096.

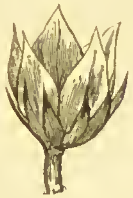


Fig. 1097.

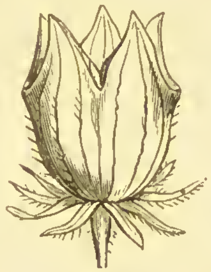


Fig. 1095. Andrœcium of *Malva.*——*Fig.* 1096. Calyx of *Althæa*, with epicalyx.——*Fig.* 1097. Calyx of *Hibiscus* surrounded by an epicalyx or involucre.

The structure of the flower may also be explained on the theory of obdiplostemony. In the case of Malva the inner whorl of stamens is absent; in Hibiscus it is represented by the teeth of the staminal tube; in Sidalcea by the columnar stamens.

The order may be divided into three tribes, which can be distinguished as follows:—

Tribe 1. *Malveæ.*—Flowers furnished with an involucre or epicalyx (*fig.* 1091). Fruit consisting of separate carpels (apocarpous) (*fig.* 1094).

Tribe 2. *Hibisceæ.*—Flowers furnished with an involucre. Fruit formed of united carpels (syncarpous).

Tribe 3. *Sideæ.*—Flowers without an involucre. Fruit apocarpous or syncarpous.

These plants are chiefly natives of the tropics and the warmer parts of temperate regions. They diminish gradually as we approach the north, and are altogether absent from the frigid zone. There are more than 1,000 species.

No plant of this order possesses any deleterious properties. The order is generally characterised by mucilaginous and demulcent qualities. From the bast of many species strong and tough fibres are obtained, and the hairs covering the seeds of certain species of *Gossypium* constitute cotton.

Order 2. STERCULIACEÆ.—This order somewhat closely resembles *Malvaceæ*; the andrœcium is obdiplostemonous; the antipetalous stamens are in some cases slightly monadelphous, and the antisepalous ones represented by staminodes. Sometimes the latter are suppressed. The stamens differ from those of the Malvaceæ in bearing perfect (4-celled) anthers. The corolla in some cases is absent, and the flowers in others are diclinous. The order *Byttneriaceæ* of some botanists is generally included in Sterculiaceæ.

Order 3. TILIACEÆ.—The plants of this order are usually trees or shrubs with alternate leaves having deciduous stipules. The sepals are free in most cases; the petals five, imbricate in the bud; the stamens ten or indefinite, free from each other, or slightly coherent at their bases into several bundles. The original prominences are in some genera divided into many filaments, sometimes as far as their bases, sometimes nearly to that point. In a few genera, on the other hand, the ten perfect stamens are found in two whorls. The anthers are 4-celled. The pistil is syncarpous, of from two to ten carpels; the ovary is usually 5-celled, with axile placentation. There is a glandular hypogynous disc.

This order resembles, in many respects, the *Malvaceæ* and *Sterculiaceæ*. It may be at once distinguished from them by having a glandular disc, and by the stamens not being monadelphous; and from the Malvaceæ also by the anthers being 4-celled. From all other *Thalamifloræ* the plants of this order may be known by their alternate simple stipulate leaves; valvate æstivation of calyx, which is also deciduous; floral envelopes in four or five divisions; stamens either distinct or polyadelphous; anthers 2-celled; hypogynous glandular disc; many-celled fruit with axile placentas; and embryo erect, straight, in the axis of fleshy albumen.

FIG. 1098.

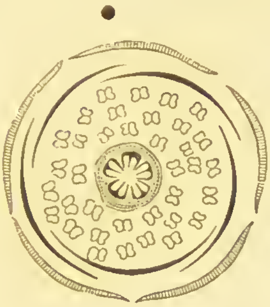


FIG. 1100.

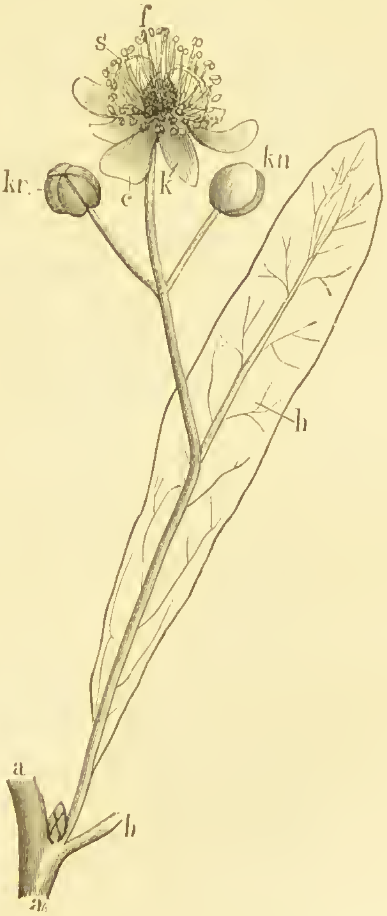


FIG. 1099.

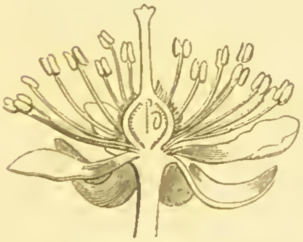


Fig. 1098. Diagram of the flower of the Lime.——*Fig.* 1099. Vertical section of the flower of the same (*Tilia europæa*) ——*Fig.* 1100. Inflorescence of *Tilia*. *a*. Axis. *b*. Leaf-stalk. *h*. Bracteole adherent to the stalk of the inflorescence. After Warming.

The only British genus is *Tilia*, the Lime tree. It is characterised by its peculiar inflorescence, which is a 3-flowered dichasium, apparently adherent to a large leaf (*fig.* 1100). It is developed in the axil of a foliage leaf, and a vegetative bud appears to be placed between it and the stem. The inflorescence is the termination of the true axillary shoot; the first two leaves of the latter are the large foliaceous body (*h*) adherent to the axis of the inflorescence, and a scale leaf opposite to it. The bud is really developed upon the axis of the inflorescence in the axil of the scale leaf. The leaf to which the axis is adherent is thus a bracteole.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 1. THALAMIFLORÆ.

1. FLOWERS with more than 20 stamens.

A. *Leaves without stipules.*	
a. *Carpels more or less distinct (at least as to the styles), or solitary.*	
1. Stamens distinct.	
Carpels immersed in a fleshy tabular thalamus	*Nymphæaceæ* (*Nelumboneæ*).
Carpels not immersed in a thalamus.	
Embryo with endosperm and perisperm	*Nymphæaceæ* (*Cabombeæ*).
Embryo naked, very minute.	
Seeds arillate	*Dilleniaceæ.*
Seeds exarillate. Albumen fleshy and homogeneous.	
Flowers hermaphrodite . . .	*Ranunculaceæ.*
Flowers unisexual . . .	*Magnoliaceæ* (*Schizandreæ*).
Seeds usually exarillate. Albumen ruminated	*Anonaceæ.*
2. Stamens united in one or more parcels.	
Calyx imbricate.	
Seeds smooth	*Hypericaceæ.*
Seeds shaggy	*Tamaricaceæ* (*Reaumurieæ*).
b. *Carpels wholly combined (at least as to the ovaries), with more than one placenta; or with a free-central placenta.*	
Placentas parietal, in distinct lines.	
Anthers versatile. Juice watery . . .	*Capparidaceæ.*
Anthers innate. Juice milky	*Papaveraceæ.*
Placentas parietal, spread over the lining of the fruit	*Bixaceæ.*
Placentas covering the dissepiments . .	*Nymphæaceæ* (*Nymphææ*).
Placentas in the axis.	
Stigma large, broad, and petaloid . . .	*Sarraceniaceæ.*
Stigma simple. Calyx imbricate.	
Leaves compound	*Ternstrœmiaceæ* (*Rhizoboleæ*).

Leaves simple.	
Petals equal in number to the sepals.	
Seeds few	*Guttiferæ.*
Seeds numerous. Petals flat	*Ternstrœmiaceæ* (*Marcgravieæ*).
Seeds numerous. Petals crumpled	*Cistaceæ.*
Petals not equal in number to the sepals.	
Styles not perfectly combined	*Ternstrœmiaceæ.*
Placentas free central	*Portulacaceæ.*
B. *Leaves with stipules.*	
a. *Carpels more or less distinct* (*at least as to the styles*).	
Carpels numerous	*Magnoliaceæ.*
b. *Carpels wholly combined* (*at least as to the ovaries*), *with more than one placenta.*	
Placentas parietal	*Bixaceæ.*
Placentas in the axis.	
Calyx with an imbricate æstivation.	
Flowers involucrate	*Chlænaceæ.*
Flowers not involucrate	*Cistaceæ.*
Calyx with a valvate æstivation.	
Stamens monadelphous. Anthers 2-celled	*Sterculiaceæ.*
Stamens monadelphous. Anthers 1-celled	*Malvaceæ.*
Stamens monadelphous. Calyx irregular, and enlarged in the fruit	*Dipterocarpaceæ.*
Stamens quite distinct	*Tiliaceæ.*

2. Flowers with less than 20 stamens.

A. *Leaves without stipules.*	
a. *Carpels more or less distinct, or solitary.*	
Anthers with recurved valves	*Berberidaceæ.*
Anthers with longitudinal dehiscence.	
Albumen abundant, embryo minute.	
Flowers unisexual. Seeds usually numerous	*Berberidaceæ* (*Lardizabaleæ*).
Flowers perfect.	
Embryo with endosperm and perisperm	*Nymphæaceæ* (*Cabombeæ*).
Embryo without perisperm.	
Albumen homogeneous.	
Sepals 2	*Fumariaceæ.*
Sepals more than 2	*Ranunculaceæ.*
Albumen ruminated. Shrubs	*Anonaceæ.*
Albumen in small quantity, or altogether wanting.	
Flowers unisexual	*Menispermaceæ.*
Flowers perfect	*Calycanthaceæ*

- b. *Carpels wholly combined* (*at least as to the ovaries*).
  - Placenta parietal.
    - Stamens tetradynamous . . . . . . *Cruciferæ.*
    - Stamens not tetradynamous.
      - Large hypogynous disc.
        - Flowers tetramerous. Fruit closed at the apex . . . . . . *Capparidaceæ.*
        - Flowers not tetramerous. Unripe fruit usually open at the apex . . . *Resedaceæ.*
      - Small hypogynous disc, or none.
        - Albumen abundant.
          - Flowers irregular . . . . . *Fumariaceæ.*
          - Flowers regular. Sap milky. Fruit without central pulp . . . *Papaveraceæ.*
            - Fruit with central pulp, or fleshy. Sap watery . . . . . *Bixaceæ.*
        - Albumen in small quantity, or wanting.
          - Calyx tubular, furrowed . . . *Frankeniaceæ.*
  - Placentas covering the dissepiments . . . *Nymphæaceæ* (*Nymphææ*).
  - Placentas axile or free central.
    - Styles distinct to the base.
      - Calyx imbricate.
        - Seeds smooth. Petals unequal-sided, without appendages . . . . *Hypericaceæ.*
        - Seeds shaggy. Petals unequal-sided, usually with appendages at the base *Tamaricaceæ* (*Reaumurieæ*).
      - Calyx slightly imbricate.
        - Petals not twisted in æstivation.
          - Ovary with a free-central placenta . *Caryophyllaceæ.*
    - Styles more or less combined.
      - Calyx imbricate, in an irregular broken whorl.
        - Flowers symmetrical . . . . *Guttiferæ.*
        - Flowers unsymmetrical, papilionaceous . *Polygalaceæ.*
      - Calyx slightly imbricate, in a complete whorl.
        - Carpels 4 or more.
          - Ovary 1-celled, with a free-central placenta . . . . . . *Portulacaceæ.*
        - Carpels less than 4.
          - Seeds comose . . . . . . *Tamaricaceæ.*
          - Seeds not comose.
            - Ovules pendulous. Petals twisted in æstivation . . . . *Canellaceæ.*
            - Ovules ascending or horizontal.
              - Petals imbricate in æstivation . *Pittosporaceæ.*
      - Calyx valvate, or but very slightly imbricate.
        - Anthers opening by pores . . . . *Tremandraceæ.*

B. *Leaves with stipules.*	
a. *Carpels distinct, or solitary.*	
Anthers with recurved valves. Carpel solitary	*Berberidaceæ.*
b. *Carpels wholly combined (at least as to the ovaries), with more placentas than one.*	
Placentas parietal.	
Leaves with involute vernation. Anthers crested, and turned inwards . . .	*Violaceæ.*
Stamens opposite to the petals. Anthers naked, and turned outwards . .	*Violaceæ* (*Sauvagesieæ*).
Placentas in the axis.	
Styles distinct to the base.	
Calyx imbricate, in an irregular broken whorl.	
Petals small, sessile	*Elatinaceæ.*
Calyx slightly imbricate, in a complete whorl.	
Petals minute	*Caryophyllaceæ* (*Paronychieæ*).
Calyx valvate	*Tiliaceæ.*
Styles more or less combined.	
Calyx imbricate, in an irregular broken whorl.	
Flowers surrounded by an involucre .	*Chlænaceæ.*
Calyx slightly imbricate, in a complete whorl.	
Sepal spurred	*Vochysiaceæ.*
Calyx valvate.	
Stamens united by their filaments into a column	*Sterculiaceæ.*
Stamens not united into a column . .	*Tiliaceæ.*

It should be particularly noticed, that although the general character of the Thalamifloræ is to have dichlamydeous flowers and polypetalous corollas, yet exceptions occur occasionally to both these characters. Thus, we find apetalous genera and species in *Ranunculaceæ*, *Magnoliaceæ*, *Berberidaceæ*, *Sarraceniaceæ*, *Menispermaceæ*, *Papaveraceæ*, *Cruciferæ*, *Canellaceæ*, *Bixaceæ*, *Violaceæ*, *Caryophyllaceæ*, *Malvaceæ*, *Sterculiaceæ*, and *Tiliaceæ*.

Again, in the orders *Anonaceæ*, *Pittosporaceæ*, *Polygalaceæ*, *Portulacaceæ*, *Tamaricaceæ*, *Ternstrœmiaceæ*, and *Dipteraceæ*, we find some monopetalous species and genera.

In *Dilleniaceæ*, *Papaveraceæ*, *Capparidaceæ*, *Resedaceæ*, *Violaceæ*, *Caryophyllaceæ*, *Portulacaceæ*, *Malvaceæ*, and *Sterculiaceæ*, some of the species have stamens more or less perigynous instead of hypogynous. Again, in some orders, as in certain *Ranunculaceæ*, *Calycanthaceæ*, *Anonaceæ*, *Nymphæaceæ*, *Portulacaceæ*, *Capparidaceæ*, *Polygalaceæ*, *Bixaceæ*, *Ternstrœmiaceæ*, *Vochysiaceæ*, *Tiliaceæ*, and *Dipterocarpaceæ*, the calyx is more or less superior.

Synopsis of the British Natural Orders of the Series Thalamifloræ.

- A. Corolla polypetalous, hypogynous.
  - 1. Ovaries many, distinct or united, each with a style, or solitary with one lateral placenta.
    - Corolla regular.
      - Sepals free. Stamens hypogynous.
        - Stamens ∞, usually many. Anthers dehiscing by slits . . . . . *Ranunculaceæ.*
        - Stamens equal and opposite to petals. Anthers dehiscing by valves . . . *Berberidaceæ.*
    - Corolla irregular.
      - Leaves exstipulate. Stamens diadelphous . *Fumariaceæ.*
  - 2. Ovary solitary, with parietal placentation.
    - Corolla regular.
      - Petals 4.
        - Stamens ∞. Sepals 2, fugacious . . *Papaveraceæ.*
        - Stamens tetradynamous . . . . *Cruciferæ.*
      - Petals 5.
        - Sepals distinct, 3 inner twisted in the bud, 2 outer smaller or wanting. Stamens ∞ *Cistaceæ.*
        - Sepals united below. Stamens iso- or diplostemonous inserted on a disc . . *Tamaricaceæ.*
      - Petals 4–5, clawed. Placentas 3 . . . *Frankeniaceæ.*
      - Petals and sepals acyclic . . . . . *Nymphæaceæ.*
    - Corolla irregular.
      - Leaves stipulate. Sepals 5. Stamens 5 free *Violaceæ.*
      - Leaves exstipulate. Fruit open at the end. Stamens ∞ . . . . *Resedaceæ.*
  - 3. Ovary solitary, with axile or free-central placentation.
    - Calyx imbricate in bud.
      - Corolla regular.
        - Placentation free central.
          - Calyx tubular . . . . . . *Caryophyllaceæ (Sileneæ).*
          - Sepals distinct.
            - Stamens opposite to the petals.
              - Sepals 2 . . . . *Portulacaceæ.*
              - Sepals 3–5.
                - Stamens 10 or fewer. Stipules 0 . . . . . *Caryophyllaceæ (Alsineæ).*
                - Stamens 5. Leaves stipulate. Petals distinct . . . *Caryophyllaceæ (Polycarpeæ).*
                - Petals minute or 0 . . *Caryophyllaceæ (Paronychieæ).*
        - Placentation axile.
          - Stamens free. Styles 3–5 . . . *Elatinaceæ.*
          - Stamens polyadelphous . . . . *Hypericaceæ.*

Calyx valvate in the bud.
  Stamens columnar . . . . *Malvaceæ.*
  Stamens free . . . . . *Tiliaceæ.*

B. Corolla partly gamopetalous, or with petals slightly united at their base . . . . *Polygalaceæ.*

Series 2.—*Disciforæ.*

In this series the sepals are usually coherent, though not always; the petals usually form a single whorl; the stamens are hypogynous, or attached to a disc which is sometimes perigynous; the ovary is generally syncarpous.

Bentham and Hooker divide this series into four cohorts.

Cohort 1.—*Geraniales.*

The flowers are usually pentamerous; there are frequently two whorls of stamens, which are then obdiplostemonous; the disc is often conspicuous, but is sometimes absent; the stamens are hypogynous, and the pistil generally syncarpous, the individual carpels being opposite to the petals.

Order 1. Linaceæ.—The plants of this order are herbs or rarely shrubs, which bear simple leaves which in a few cases are furnished with small stipules; they are arranged in spirals, or may be opposite or whorled. The inflorescence is cymose, and the flowers are regular, either pentamerous or tetramerous.

Fig. 1101.

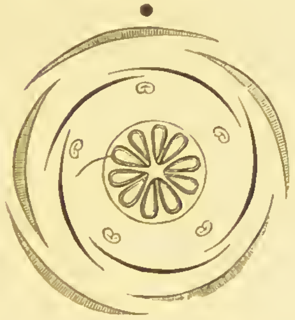


Fig. 1102.

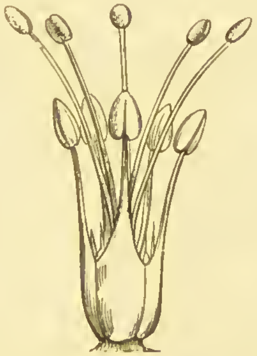


Fig. 1103.

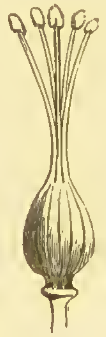


Fig. 1101. Diagram of the flower of the Flax plant (*Linum usitatissimum*).——*Fig.* 1102. Sporophylls of the same, showing the monadelphous stamens surrounding the pistil.——*Fig.* 1103. Pistil of the same, with distinct styles and capitate stigmas.

The calyx is imbricate and persistent, the corolla twisted and fugacious. The stamens are united at their bases to form a hypogynous ring, from which proceed an equal number of teeth-like processes or staminodes. The latter are opposite to the petals. The disc is represented by ten small glands, one lying outside each stamen; the carpels form a syncarpous ovary, each loculus of which is divided more or less completely into two by a spurious dissepiment (*fig.* 1101). The styles are free, and each bears a capitate stigma. The fruit is a capsule which dehisces septicidally. There are two ovules in each loculus, which are separated by the incomplete dissepiment. The seeds contain a little albumen.

The order *Erythroxylaceæ* of some botanists is included in Linaceæ by Bentham and Hooker. It differs from the type described in having a ligulate corolla, ten perfect stamens, and a drupaceous fruit.

The plants of this order are chiefly natives of the south of Europe, Brazil and some other parts of South America, the West Indies, and the north of Africa, but they are more or less distributed over most regions of the globe. There are about 160 species. The order is of great importance as the source of Flax.

Order 2. HUMIRIACEÆ.—A small order of tropical American trees, with alternate coriaceous leaves. The flowers have twenty or more monadelphous stamens, a drupaceous fruit, and orthotropous seeds.

Order 3. MALPIGHIACEÆ.—A tropical order of trees or shrubs which includes some lianes whose stem structure shows certain anomalous features. The leaves are opposite, and the flowers regular or obliquely zygomorphic. The sepals have characteristic glands at their bases. The stamens are ten, and may be monadelphous or distinct; the connectives are fleshy and produced beyond the anther lobes. The ovary is usually 3-celled, and the fruit is samaroid, drupaceous, or a woody nut.

Order 4. ZYGOPHYLLACEÆ.—A small order of herbs or shrubs with opposite stipulate leaves. The flowers are actinomorphic and usually contain a fleshy toothed disc. In some this is replaced by separate glands.

Order 5. GERANIACEÆ.—The limits of this Natural Order are assigned differently by different botanists. Bentham and Hooker consider it to include the plants which by some writers are set apart in distinct orders under the names of *Balsaminaceæ*, *Vivianaceæ*, *Tropæolaceæ*, *Limnanthaceæ*, and *Oxalidaceæ*. Taking the more restricted view, it presents the following features. The majority of the plants are herbaceous. with stipulate leaves, either alternate or opposite. The flowers in all the genera but *Pelargonium* are regular and actinomorphic. The inflorescence is a cymose umbel or a scorpioid cyme. The flower is pentamerous; the sepals are imbricate and persistent; the petals are clawed, twisted, and fugacious. The stamens are monadelphous and obdiplostemonous, the inner whorl being in some cases represented by staminodes. There are five glands at the base of the stamens of the inner (antisepalous) whorl. The pistil is composed of five carpels, which are opposite to the petals. They are seated on a disc which grows up between them as the fruiting stage is reached, forming a long beak or carpophore (*fig.* 1106), to which the styles remain attached. The styles separate at the top (*fig.* 1105). The fruit is a collection of five cocci, which separate from one another and from the base of the beak when ripe and curl up or become spirally twisted, the upper part of the styles remaining adherent to the top of the beak (*fig.* 1108). In some species the separation is effected with violence, the carpels open septicidally, and the seed is ejected from the coccus. In others (*Erodium*, *Pelargonium*) this does not take place, but the cocci eventually become detached, and by the hygroscopic character of the adherent portion of the style are buried in the soil. The seeds are one or sometimes two in each carpel, and are exalbuminous.

Fig. 1104.

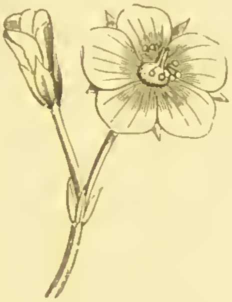


Fig. 1105.

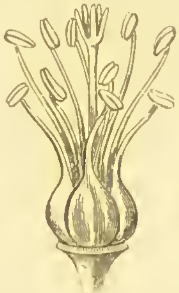
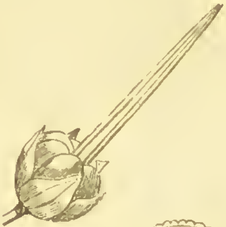


Fig. 1106.



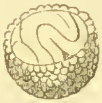


Fig. 1107.

Fig. 1104. A portion of the flowering stem of *Geranium sylvaticum.*——*Fig.* 1105. The andrœcium and gynœcium of the same.——*Fig.* 1106. The pistil, partially matured, surrounded by the persistent calyx.——*Fig.* 1107. Transverse section of the seed.

Geranium has ten perfect stamens, while *Erodium* has five staminodes. *Pelargonium* has the three most anterior stamens of the outer whorl suppressed or represented by staminodes, and is peculiar in having the posterior sepal prolonged into a spur, which becomes adnate to the peduncle. *Monsonia* and *Sarcocaulon* have five phalanges of stamens opposite to the petals.

The plants of this order are distributed over various parts of the world, but they abound at the Cape of Good Hope. There are nearly 550 species.

Astringent, resinous, and aromatic qualities are the more important properties of these plants. Many are remarkable for the beauty of their flowers, and others for the agreeable odours of their leaves and flowers, which render them useful in perfumery.

FIG. 1108.

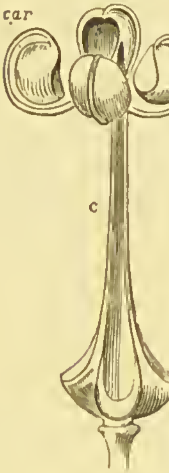


Fig. 1108. The carpophore, *c*, of a species of *Geranium*, with the rolled-back carpels, *car*.

The structure of the flower has been the subject of much discussion, and three hypotheses have been advanced to explain it. The first is that of St. Hilaire, who suggested that the antipetalous stamens are due to chorisis of the petals, and that consequently each petal and the stamen standing before it are representative of a single member of the corolla. On this view there would be only one truly staminal whorl, which would have its proper position opposite to the sepals. An objection to this view has been urged by Celakowski, based upon the similar orientation of the vascular bundles in the petal and the stamen in front of it, which seems to indicate that they are representatives of independent leaves and not superposed portions of a single one.

The second hypothesis was put forward by Braun. He suggested that a whorl has been suppressed between the petals and the outer stamens, and that this would have been a whorl of petals, making the corolla biseriate. If this hypothesis were adopted, with the modification of considering this suppressed whorl one of stamens, we should have a typical structure similar to that suggested in *Malvaceæ*, viz. three whorls of stamens regularly alternating with the petals and the carpels. Braun suggested that the five green glands of the genus *Geranium* which occupy the position in question are the representatives of the missing whorl. An objection to this view is that in no related genera do we find traces of the missing whorl. The suggestion that the glands represent it appears untenable in view of the fact that in the genus *Oxalis* (sometimes included in this order) there are ten glands, one behind each stamen.

The third view is that of Celakowski. He suggests that the flower is capable of explanation on the theory of obdiplostemony;

that the antipetalous stamens are really the inner whorl, and have in course of growth been forced outwards till they come to be beyond the true inner whorl. The evidence for this view is strong, for in *Parnassia* (*Saxifragaceæ*) the staminodes, which are antipetalous, are the interior whorl in the bud. Also, in *Limnanthes* the stamens, which are antipetalous in the mature flower, are antisepalous in the bud. In many of the obdiplostemonous *Caryophyllaceæ* the stamens, which at their insertion are antisepalous, are at their summits antipetalous. Further, the vascular bundles which enter these antipetalous stamens are either more to the centre of the floral axis than those which enter the others, or are in line with them.

The main difficulty in the way of this hypothesis is that the carpels are antipetalous, whereas they ought to alternate with this whorl of displaced stamens. Celakowski met this objection by saying that this is probably due to the recession of the stamens leaving more room opposite to them. This seems to follow the law of phyllotaxis, that the succeeding members are produced opposite to the greatest space between the preceding ones.

The arrangements of the andrœcium in *Monsonia* (*fig.* 1109) and *Sarcocaulon* are peculiar. There are fifteen stamens, arranged in five antipetalous phalanges; each phalanx consisting of one perfect central stamen and an imperfect one, with only half an anther, attached to it on each side, just as is the case in *Fumaria*. It has been suggested that this peculiarity is due to obdiplostemony and chorisis of the inner stamens, which after dividing coalesce, as far as their filaments are concerned, with the stamens of the outer whorl, each half of the chorised stamen uniting with the entire stamen nearest to it.

FIG. 1109.

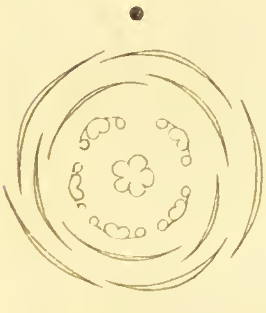


FIG. 1110.

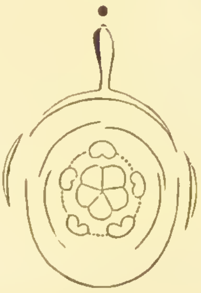


FIG. 1111.

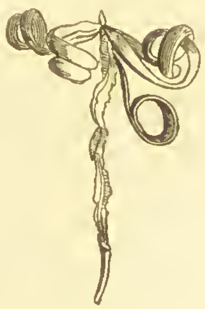


Fig. 1109. Floral diagram of *Monsonia.* —*Fig.* 1110. Diagram of the flower of *Impatiens parviflora.*——*Fig.* 1111. Capsule of Touch-me-not (*Impatiens noli-me-tangere*), with recurved coiled-up valves.

Order 6. BALSAMINACEÆ.—The plants of this order are herbaceous plants, with semi-transparent juicy stems and simple leaves occasionally bearing glands at the bases of their petioles. The flowers are zygomorphic; the antipetalous stamens are suppressed. The posterior sepal is spurred, and the two anterior ones are small or absent; the anterior petal is large. All the perianth leaves are coloured. The anthers are almost syngenesious and cover the pistil. The fruit is a capsule, which opens with some violence from the base upwards, scattering the seeds. The latter are exalbuminous.

Order 7. Vivianaceæ.—A small order of South American plants with regular flowers, having ten free stamens, a loculicidal capsule, and exalbuminous seeds.

Order 8. Tropæolaceæ.—A small order of herbaceous plants which bear peltate exstipulate leaves, and in some cases climb by means of sensitive petioles. They have zygomorphic flowers; the posterior sepal, or according to some writers the receptacle under it, is prolonged into a spur; the three anterior petals are fringed and furnished with a claw; the two median stamens, one belonging to each whorl, are suppressed; the fruit is a tricarpellary schizocarp, much like that of *Geranium*, but there is no beak. The seeds are exalbuminous.

Fig. 1112.

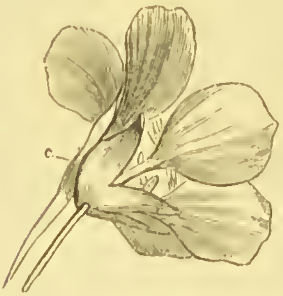


Fig. 1113.

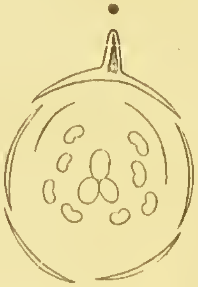


Fig. 1112. Flower of *Tropæolum*. *c.* Spurred calyx.——*Fig.* 1113. Diagram of the flower of *Tropæolum pentaphyllum*.

Order 9. Limnanthaceæ.—In this order also the fruit is a schizocarp; the carpels are nearly free, but have a common gynobasic style. The carpels are in front of the sepals instead of the petals, as in the other orders. The stamens are perigynous.

Order 10. Oxalidaceæ.—The plants of this order are chiefly herbs with rhizomes; the leaves are compound, with entire leaflets. The flowers are actinomorphic; the disc is represented by small glands at the bases of the antisepalous stamens, or of all of them. The stamens, though in two whorls, are monadelphous; the fruit is a capsule. The seeds in some species are provided with a fleshy integument, which bursts with elasticity when the fruit is ripe, and expels the seeds.

FIG. 1114.

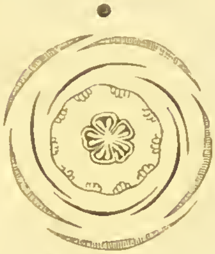


FIG. 1115.

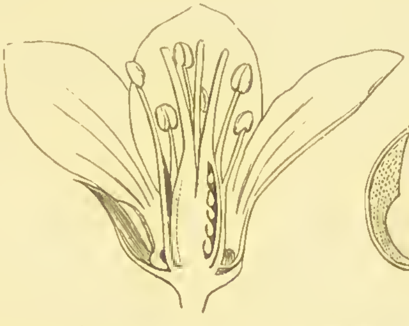


FIG. 1116.

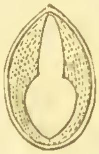


Fig. 1114. Diagram of the flower of *Oxalis.* —*Fig.* 1115. Vertical section of the flower of the same. —*Fig.* 1116. Vertical section of the seed.

Some species of *Oxalis* have cleistogamous flowers; the leaves of this genus and of *Averrhoa* show nyctitropic movements.

The whole order is remarkable for an acid juice, which is due to the presence of binoxalate of potassium. The order is a prominent feature of the flora of the Cape of Good Hope. It comprises about 330 species.

Order 11. RUTACEÆ.—The plants of this order are trees, shrubs, and rarely herbs, with numerous etherial oil reservoirs or glands on their leaves and stems. The flowers are either pentamerous or tetramerous, and are usually actinomorphic and obdiplostemonous. There is a well-marked disc, which in some cases raises the carpels well above the level of the other parts of the flower, forming a fleshy gynophore. On this disc are seated the carpels, which in some cases are almost apocarpous, but the styles are usually united.

The order is divided into seven tribes, *Cusparieæ*, *Ruteæ*, *Diosmeæ*, *Boronieæ*, *Zanthoxyleæ*, *Toddaleæ*, and *Aurantieæ*.

Cusparieæ.—Flowers with five stamens and a gamopetalous corolla.

Ruteæ.—The fruit is a loculicidal capsule. *Ruta graveolens* is peculiar in having cymes of flowers, of which the terminal one is pentamerous and the lateral ones tetramerous. *Dictamnus* has a zygomorphic flower.

Diosmeæ.—An African group of heather-like shrubs with simple leaves.

Boronieæ.—These plants are Australian.

Zanthoxyleæ.—An American group, chiefly with diœcious and polygamous flowers.

Toddaleæ.—Gynœcium syncarpous; fruit dry or succulent, indehiscent, furnished with a wing.

Aurantieæ.—The leaves show a peculiar articulation between the blade and the petiole, the latter being winged or flattened. The calyx is gamosepalous, and the fruit is a hesperidium, or multilocular berry with a thick tough outer layer. The carpels are separated from each other by thin dissepiments, and their interior is filled by

Fig. 1117.

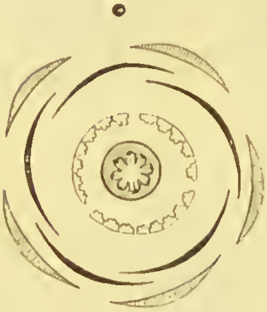


Fig. 1118.

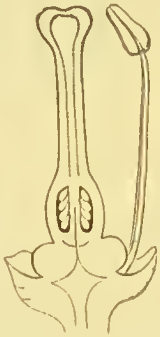


Fig. 1119.

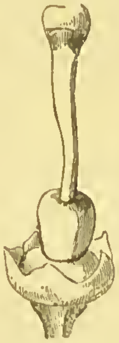


Fig. 1120.

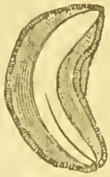


Fig. 1121.

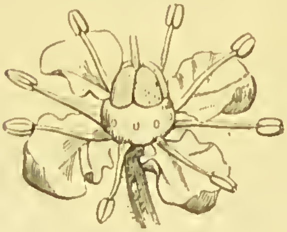


Fig. 1122.

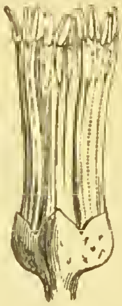


Fig. 1117. Diagram of the flower of the Orange (*Citrus Aurantium*).——*Fig.* 1118. Vertical section of the pistil, showing a portion of the disc at its base, and a solitary hypogynous stamen.——*Fig.* 1119. Pistil of the Orange, with disc at its base, and the calyx: the petals and stamens have been removed.——*Fig.* 1120. Vertical section of the seed of the Common Rue (*Ruta graveolens*).——*Fig.* 1121. Flower of *Ruta*, showing the large hypogynous disc, on the outside of which the stamens are inserted.——*Fig.* 1122. Andrœcium of the Orange, showing polyadelphous stamens.

a pulpy development from peculiar hairs which arise on the inner surface of the carpellary walls. The stamens in the genus *Citrus* are only in one whorl of five, but they split towards their apices irregularly, forming a number of phalanges (*fig.* 1122). The seeds sometimes contain several embryos.

The *Ruteæ* are found chiefly in the southern part of the temperate zone and in Northern Asia; the genera *Diosma*, *Barosma*, &c., abound at the Cape of Good Hope; other genera are found in Australia, and some in equinoctial America. *Zanthoxyleæ* are mostly American, *Aurantieæ* chiefly East Indian. There are about 620 species.

The *Ruteæ* are generally characterised by a powerful penetrating odour and bitter taste. In medicine they are employed as antispasmodics, tonics, febrifuges, diuretics, &c. The *Zanthoxyleæ* are almost universally characterised by pungent and aromatic properties, and sometimes by bitterness. In medicine, they have been employed as stimulants, sudorifics, febrifuges, tonics, sialogogues, and emmenagogues. The *Aurantieæ* abound in glands containing essential oils, which render them fragrant. These volatile oils are especially abundant in the leaves, the petals, and the rind of the fruit. The latter also contains a bitter tonic principle. The pulp of the fruit has an acid or somewhat saccharine taste; and the wood is always hard, and of a compact nature.

Order 12. SIMARUBACEÆ.—The plants of this small order differ from the Rues by the absence of the reservoirs of etherial oil. The flowers are in some cases diclinous, and the pistil is in some species apocarpous, the carpels then becoming succulent. Other species have a samaroid fruit.

Order 13. OCHNACEÆ.—An order of tropical shrubs or trees; the pistil is apocarpous, but the carpels are inserted on a large fleshy disc, to which their gynobasic styles are attached. The fruits are small drupes.

Order 14. BURSERACEÆ.—A tropical order of trees or shrubs with a fragrant gum-resinous juice.

The flowers are actinomorphic, the gynœcium syncarpous. The disc is perigynous; the ovules are in pairs in the loculi of the ovary, and are attached to a placenta at the apex of the loculus.

Order 15. MELIACEÆ.—An order of trees and shrubs with usually pinnate leaves without stipules. The stamens are monadelphous, and stipule-like teeth occur on the tube.

Order 16. CEDRELACEÆ.—A small order, now usually incorporated with *Meliaceæ*, from which it differs by the stamens being less completely monadelphous, and by the seeds being winged.

Some of the plants of this order yield valuable timber. *Swietenia Mahogani* is the Mahogany tree; the wood of species of *Cedrela* is used for making cigar boxes; it is often erroneously called *cedar-wood.*

Order 17. CHAILLETIACEÆ.—A small order of tropical trees or shrubs, with stipulate leaves, ten perigynous stamens, of which the outer whorl is petaloid and sterile. There are only about ten species.

Cohort 2.—*Olacales.*

The plants of this cohort all have pendulous ovules with a dorsal raphe. The gynœcium is always syncarpous, and the seeds albuminous.

Order 1. OLACACEÆ.—An order of trees or shrubs with alternate entire simple exstipulate leaves, with a syncarpous ovary showing free-central placentation. The calyx is gamosepalous and accrescent, enlarging so as to cover the fruit; the latter is drupaceous, and the seeds are without integuments.

Order 2. ICACINACEÆ.—A small order formerly included with the last, from which it differs in the calyx not being accrescent and the seeds possessing integuments.

Order 3. CYRILLACEÆ.—A small order including only six species, differing but little from *Olacaceæ.*

Order 4. PHYTOCRENACEÆ.—A small order formerly included in the *Artocarpaceæ*, a group now held to belong to the tribe *Moreæ*, of the *Urticaceæ*; it differs from them by the possession of a biseriate perianth, and by the seeds being albuminous. The flowers are diclinous.

Order 5. AQUIFOLIACEÆ or ILICACEÆ.—The plants of this order are shrubs or trees with leathery simple leaves, in some species spiny, with very small stipules. The flowers are small and are borne in the axils of the foliage leaves; they are sometimes diclinous and diœcious. The perianth leaves are slightly united at their bases; there is no disc; the ovary is 2–6-celled, with one ovule in each cell, and the fruit is fleshy and indehiscent.

The Holly (*Ilex Aquifolium*) is the only European species. Several South American species are rich in *caffeine.*

Cohort 3.—*Celastrales.*

The flowers are actinomorphic, either pentamerous or tetramerous; there is only one whorl of stamens, which in some orders is antipetalous, in others antisepalous; the disc is present; the seeds are erect, with a ventral raphe, and in most cases contain endosperm.

Order 1. Celastraceæ.—These are shrubby plants with simple leaves and deciduous stipules. The sepals and petals are four to five each, imbricate in æstivation. The stamens are equal in number to the petals, and are inserted with them on a large flat disc in which the ovary is sunk, so that the stamens are somewhat perigynous. The fruit is a loculicidal capsule.

In *Euonymus europæus*, the Spindle tree, the seeds have an orange-red arillode. The embryo is green.

Order 2. Hippocrateaceæ.—A small order often included in *Celastraceæ*. The plants are chiefly topical lianes. The flowers have three stamens, which are monadelphous, and the fruit is baccate or samaroid.

Order 3. Stackhousiaceæ.—A small order of Australian herbs or shrubs, with entire leaves with very minute stipules. The stamens are perigynous, and the fruit consists of three to five indehiscent carpels attached to a central persistent column.

Order 4. Rhamnaceæ.—The plants of this order are trees or shrubs, many of which bear thorns. The flowers are inconspicuous; those of some species are diclinous. They are either pentamerous or tetramerous, but the carpels are generally only three in number. The calyx is valvate; the petals are small and hoodlike, and embrace the stamens which are inserted opposite to them. A fleshy disc lines the interior of the calyx, and the ovary is partially or completely surrounded by it so as to be almost or quite inferior. The fruit in some species is capsular, in others drupaceous. The embryo is often green or yellow.

Rhamnus catharticus is diœcious; its flowers are dimorphic. *R. purshianus* yields Cascara Sagrada. *R. infectorius* has berries which produce a yellow dye.

Fig. 1123.

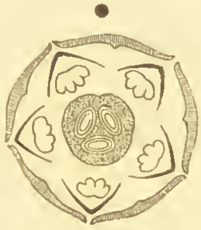


Fig. 1123. Diagram of the flower of Buckthorn (*Rhamnus catharticus*).

Order 5. Ampelidaceæ or Vitaceæ.—The plants of this order are shrubs with swollen nodes; they are nearly all climbers, bearing tendrils apparently opposite their leaves. The leaves are generally palmate and bear stipules. In some cases they are simple, in others compound. The inflorescence is panicled, often taking the form of a thyrsus; it occupies a similar position to the tendrils. The flowers are hypogynous or slightly perigynous; the calyx is small, with the limb often obsolete; the petals are valvate in the bud, and are often shed in a single piece before they have expanded. The stamens are equal in number to the petals and opposite to them. A 5-lobed disc is between the stamens and the pistil. The ovary is 2-celled, with two erect ovules in each cell; the fruit is a berry.

The tendrils are axial structures, the branching being sympodial. Each tendril is the termination of an axis which bears one leaf or two. In the former case the bud in the axil of the leaf develops strongly and forms a part of the sympodium, the tendril being displaced laterally by the stronger growth of the branch. The parts of the sympodium consist alternately of one and of two internodes, so that every third leaf has no tendril opposite to it. Each leaf has a bud in its axil; in the case of the leaves which are apparently opposite to the tendrils, this is an accessory bud to the sympodial shoot; in the case of the other leaves it is the only one produced, and is therefore a normal bud. These buds either remain undeveloped, or give rise to dwarf shoots. The inflorescences are terminal, becoming displaced in the same way as the tendrils.

Cohort 4.—*Sapindales.*

The plants are chiefly trees or shrubs. The calyx has an imbricate æstivation; the gynœcium is usually syncarpous, the ovules ascending, with a ventral raphe. The seeds are usually exalbuminous.

Order 1. SAPINDACEÆ.—The plants of this order are trees or shrubs, many of which climb by means of branch-tendrils. The leaves are compound. The flowers are obliquely zygomorphic, having two petals longer than the other three. The stamens

FIG. 1124.

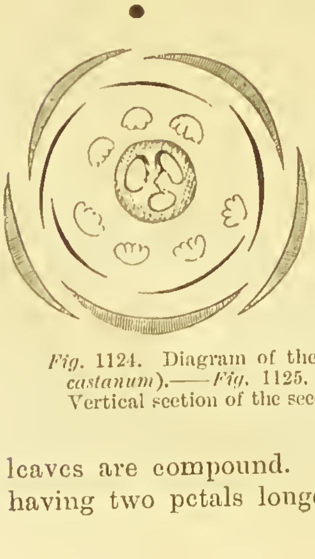


FIG. 1125.

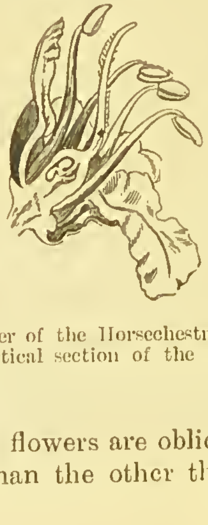


FIG. 1126.

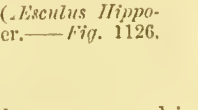


Fig. 1124. Diagram of the flower of the Horsechestnut (*Æsculus Hippocastanum*).——*Fig.* 1125. Vertical section of the flower.——*Fig.* 1126. Vertical section of the seed.

are typically twice the number of the petals, but are placed in a single whorl. Two or three of the antisepalous stamens are often suppressed (*fig.* 1124). There is a disc external to the andrœcium; the ovary is 3-celled, with one to two ovules in each cell; the seeds are exalbuminous, and the embryo is often bulky and curved (*fig.* 1126).

This order has been divided into four sub-orders as follows:—

Sub-order 1. *Sapindeæ.*—Leaves alternate. Ovules usually solitary. Embryo generally curved or sometimes straight.

Sub-order 2. *Hippocastaneæ.*—Leaves opposite. Ovules two in a cell, of which one is ascending, and the other suspended. Embryo curved, with a small radicle and large fleshy consolidated cotyledons.

Sub-order 3. *Dodoneæ.*—Leaves alternate. Ovules two or three in a cell. Embryo spiral.

Sub-order 4. *Meliosmeæ.*—Leaves alternate. Flowers very irregular. Stamens five, three of which are abortive, and only two, therefore, fertile. Ovules two in each cell, suspended. Fruit drupaceous. Embryo folded up.

Bentham and Hooker include the *Meliosmeæ* in the order *Sabiaceæ.*

These plants are chiefly found in tropical regions, especially those of South America and India; some occur in temperate climates, but none inhabit the cold northern parts of the globe. There are no native plants of this order in Europe. The Horsechestnut, now so well known in this country, is only naturalised among us. There are nearly 400 species.

One of the most prominent characteristics of the plants of this order is the presence of a saponaceous principle, from which its common name is derived. Many are poisonous in all their parts; but it is more frequently the case that, while the root, leaves, and branches are dangerous, the fruits are innocuous, or even palatable. It sometimes happens, as in the Litchi and Longan fruits, that while the pericarp is wholesome, the seeds are dangerous. Some plants of the order are astringent and aromatic; others are diaphoretic, diuretic, and aperient; and some are valuable timber trees.

Order 2. ACERACEÆ.—This order is included in the last by Bentham and Hooker, who consider it only a tribe of Sapindaceæ. The flowers are regular, and the gynœcium is composed of only two carpels. In some species the flowers are diclinous and polygamous. The stamens are typically ten, but the two median ones are suppressed. The fruit is a samara. The embryo has a pair of wrinkled cotyledons.

Order 3. Staphyleaceæ.—A small order of shrubby plants generally included in *Sapindaceæ*. There are only fourteen species.

Order 4. Sabiaceæ.—A small order found in the East Indies. There are only two genera and nine species. They closely resemble the *Anacardiaceæ*, but are distinguished from the latter by having antipetalous stamens and distinct carpels.

Order 5. Anacardiaceæ.—The plants of this order are mainly tropical trees or shrubs, with simple or compound exstipulate leaves and a milky acrid or resinous juice. The flowers are usually actinomorphic, and in many cases diclinous; the stamens vary in number, being in some cases isomerous with the petals, in others twice as numerous, and in others indefinite; their insertion is perigynous. In some cases there is a disc, but in others it is absent.

Fig. 1127.

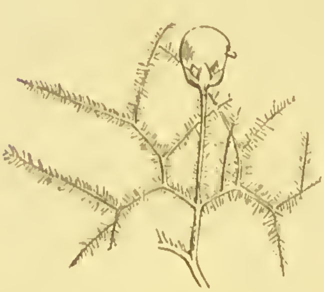


Fig. 1127. Flowering branch of the *Rhus Cotinus*, or Wig-tree, with one branch bearing fruit, and the others covered with hair-like appendages and sterile.

The plants of this order are chiefly found in the tropical regions of the globe, although a few are found in the south of Europe and in other extra-tropical warm districts. There are about 110 species.

Several species of *Rhus* are cultivated in this country. *R. Toxicodendron*, the poisonous Sumach, grows in North America. *Mangifera indica* is the Mango tree. *Pistachia vera* yields edible seeds; *P. terebinthus* yields turpentine.

Anomalous Orders.

Coriariaceæ.—A small order whose affinities seem to be with *Ochnaceæ*, with which it agrees in having distinct carpels placed on an enlarged disc. It differs from that order by having opposite leaves, sometimes polygamous flowers, persistent fleshy petals, long linear distinct stamens, and no style.

Moringaceæ.—A small order comprising only four species. They are trees with bi- or tri-pinnate leaves and thin deciduous stipules. The calyx is lined by a fleshy disc. The ovary is stalked, superior, 1-celled, with three parietal placentas. The fruit is a long capsule with loculicidal dehiscence.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 2. Discifloræ.

1. Flowers with more than 20 stamens.

Carpels more or less distinct (at least as to the styles), or solitary, superior or partially inferior. Stamens perigynous . . . . *Anacardiaceæ.*
Carpels wholly combined (at least as to the ovaries), superior. Stamens hypogynous . *Humiriaceæ.*

2. Flowers with less than 20 stamens.

A. *Leaves generally without stipules.*
a. *Carpels more or less distinct, or solitary.*
Leaves without dots.
Albumen abundant . . . . . . *Zygophyllaceæ.*
Albumen absent . . . . . . *Anacardiaceæ.*
Leaves dotted . . . . *Burseraceæ.*

b. *Carpels wholly combined (at least as to their ovaries).*
Styles distinct to the base.
Calyx valvate . . . . *Vivianiaceæ.*
Calyx imbricate . . . . *Linaceæ.*
Styles more or less combined.
Calyx valvate or united, or but very slightly imbricate.
Stamens hypogynous.
Calyx generally enlarging with the fruit . *Olacaceæ.*
Calyx not enlarging with the fruit.
Stamens opposite to the petals, isomerous . . . . . . *Rhamnaceæ*
Stamens alternate with the petals, isomerous.
Leaves compound . . . . *Burseraceæ.*
Leaves simple . . . . . *Icacinaceæ.*
Stamens more or less perigynous.
Flowers irregular, ovules suspended . . *Tropæolaceæ.*
Flowers regular, ovules erect . . . *Limnanthaceæ.*
Calyx imbricate.
Style gynobasic.
Stamens arising from scales . . . *Simarubaceæ.*
Stamens not arising from scales.
Styles wholly combined.
Flowers perfect . . . . . *Rutaceæ.*
Flowers polygamous . . . . *Zanthoxyleæ of Rutaceæ.*

Styles divided at the apex.
Flowers irregular, fruit usually with elastic valves . . . . *Balsaminaceæ*
Style not gynobasic.
Calyx much imbricate, in an irregular broken whorl.
Petals with appendages at their base.
Leaves alternate . . . . *Sapindaceæ.*
Petals without appendages at their base.
Leaves opposite . . . . *Aceraceæ.*
Calyx but little imbricate, in a complete whorl.
Carpels 4 or more.
Seeds winged . . . . . *Cedrelaceæ.*
Seeds wingless.
Stamens united into a long tube *Meliaceæ.*
Stamens distinct, or nearly so.
Leaves dotted.
Seeds amygdaloid . . . *Aurantieæ of Rutaceæ.*
Leaves without dots.
Seeds erect . . . . *Celastraceæ.*
Carpels less than 4.
Petals imbricate.
Ovules suspended . . . . *Cyrillaceæ.*
Ovules erect . . . . . *Celastraceæ.*

B. *Leaves generally with stipules.*

a. *Carpels distinct, or solitary.*
Carpels several . . . . *Coriariaceæ.*

b. *Carpels wholly combined (at least as to their ovaries), with more placentas than one.*
Placentas parietal . . . . *Moringaceæ.*
Placentas in the axis.
Styles distinct to the base.
Petals conspicuous, stalked . . . . *Malpighiaceæ.*
Styles more or less combined, gynobasic.
Gynobase fleshy . . . . . . *Ochnaceæ.*
Gynobase dry.
Leaves regularly opposite . . . . *Zygophyllaceæ.*
Leaves more or less alternate.
Fruit beaked . . . . . . *Geraniaceæ.*
Fruit not beaked . . . . . *Oxalidaceæ.*
Styles more or less combined, not gynobasic.
Calyx much imbricate, in an irregular broken whorl.
Flowers not surrounded by an involucre . *Sapindaceæ.*

Calyx but little imbricate, in a complete whorl.
Stamens 3, sepals and petals pentamerous . . . . *Hippocrateaceæ.*
Stamens more than 3.
Calyx glandular.
Petals without appendages . . . *Malpighiaceæ.*
Calyx not glandular.
Leaves simple.
Petals united by their claws into a tube . . . . . *Stackhousiaceæ.*
Leaves compound.
Petals distinct . . . . . *Staphyleaceæ.*
Calyx valvate.
Stamens opposite to the petals, isomerous.
Seeds 1 in each cell . . . . . *Rhamnaceæ.*
Stamens opposite to the petals if isomerous, anthers versatile, seeds 2 in each cell . . . . *Vitaceæ.*
Stamens twice as many as the petals . *Burseraceæ.*

The following exceptions may be noted to the characters usually distinctive of the Discifloræ. We have apetalous species in *Zygophyllaceæ*, *Geraniaceæ*, *Balsaminaceæ*, *Rutaceæ*, *Simarubaceæ*, *Burseraceæ*, *Olacaceæ*, *Celastraceæ*, *Rhamnaceæ*, *Sapindaceæ*, *Anacardiaceæ*, and some others.

Gamopetalous corollas are sometimes found in *Humiriaceæ*, *Rutaceæ*, *Balsaminaceæ*, *Meliaceæ*, and *Stackhousiaceæ*.

In *Geraniaceæ*, *Balsaminaceæ*, *Tropæolaceæ*, *Oxalidaceæ*, *Aceraceæ*, *Anacardiaceæ*, *Malpighiaceæ*, *Linaceæ*, &c., the disc is small, or entirely or partially absent. The ovary is more or less inferior in some *Olacaceæ* and *Rhamnaceæ*; and the placentation is parietal instead of axile in some *Ochnaceæ* and *Moringaceæ*.

Synopsis of the British Natural Orders of the Series Disciforæ.

A. Corolla completely polypetalous, inferior.
Calyx imbricate in the bud.
Corolla irregular . . . . *Balsaminaceæ.*
Corolla regular.
Stamens in an hypogynous ring.
Stamens 4—5. Stipules absent . . . *Linaceæ.*
Stamens 10 Ovary 5-celled, many-seeded . *Oxalidaceæ.*
Stamens 10. Leaves stipulate. Ovary 5-celled, with 1 seed in each cell . . *Geraniaceæ.*
Stamens free.
Style solitary. Stamens and petals 4—5, inserted on an hypogynous disc . . *Celastraceæ.*

Calyx valvate in the bud.
Stamens perigynous, opposite to the petals . . *Rhamnaceæ*
B. Corolla gamopetalous, or with petals connate at the base.
Fruit fleshy . . . . *Aquifoliaceæ.*

Series 3.—*Calycifloræ.*

The calyx is usually gamosepalous, and the stamens perigynous or epigynous; the gynœcium may be apocarpous or syncarpous.

Cohort 1.—*Rosales.*

The stamens are generally perigynous, but the epigynous condition occurs in some orders. The gynœcium is usually simple or apocarpous, rarely syncarpous. The ovary is generally superior, but not in all cases; the placentation is usually marginal or axile; the styles are in most instances solitary, or if numerous, usually distinct, though in a few cases they are coherent.

Fig. 1128.

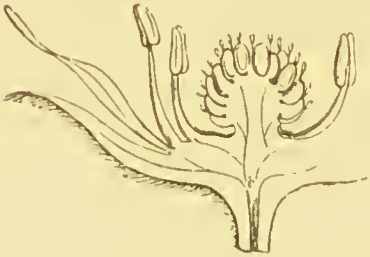


Fig. 1129.

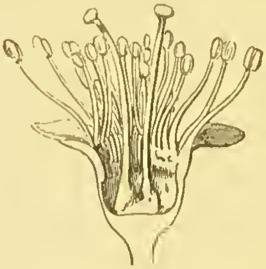


Fig. 1128. Perigynous flower of Strawberry.—*Fig.* 1129. Perigynous stamens of Cherry.

Order 1. Rosaceæ. The plants of this order are trees, shrubs, or herbs, with alternate, stipulate, often compound leaves. The flowers are actinomorphic, except in a few cases which are zygomorphic through irregularity in size of the petals; in position the odd sepal is posterior. The thalamus shows a great deal of variation; in some cases it is convex, in others elongated, in others concave, and in some tubular. In the latter case the tube may remain open and have the carpels attached to its sides and remaining free, or it may become succulent and surround several basal carpels which also become succulent, and in the progress of growth may become united with the fleshy thalamus and with each other, so that the fruit is finally spuriously syncarpous and inferior. The calyx is gamosepalous, sometimes partly adherent to the receptacular tube; it has usually five sepals, which are so arranged that the odd one is posterior. It is in many cases surrounded by an epicalyx of five bract-like bodies, which have been considered as the fused stipules of the sepals (*fig.* 1130). The petals are sometimes, though rarely, absent. The stamens are usually indefinite, but the number varies a good deal, as few as four or five being met with in some genera. The carpels are 1—∞, apocarpous; they become spuriously syncarpous in the tribe *Pomeæ*. The fruit may be a drupe, a cynarrhodon or a pome, or an etærio of achenes or of drupels, or a group of follicles. The seeds are exalbuminous.

FIG. 1130.

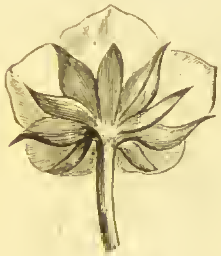


FIG. 1131.

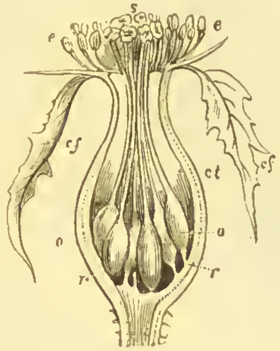


Fig. 1130. Flower of Strawberry, surrounded by a stipular epicalyx.——*Fig.* 1131. Vertical section of the flower of the Rose. *r*, *r*. Concave thalamus, upon which are placed several carpels, *o*, *o*, each with a style and stigma, *s*.

The order has been divided in different ways by many botanists, but it may be conveniently regarded as comprising five sub-orders, some of which include two or more tribes.

Sub-order 1. *Amygdaleæ* or *Drupaceæ*.—These are trees or shrubs with simple leaves and caducous stipules. The stamens are frequently twenty to thirty; the pistil is monocarpellary and bears two ovules; it becomes a drupe, containing usually a solitary seed.

In the Almond the mesocarp of the drupe becomes dry, and the endocarp is furrowed and coriaceous. *Prunus Laurocerasus*, the Cherry Laurel, has evergreen leaves and resembles in appearance the true Laurel. The plants of this sub-order contain various glucosides, one of the products of decomposition of which is prussic acid.

Sub-order 2. *Chrysobalaneæ.*—These are tropical plants, which differ from the last sub-order mainly in having zygomorphic flowers and a gynobasic style.

Sub-order 3. *Roseæ.*—These are shrubs or herbs with simple or compound leaves and generally adherent stipules. The carpels are one or more, superior, and free from the tube of the thalamus; the styles are lateral or nearly terminal.

Fig. 1132.

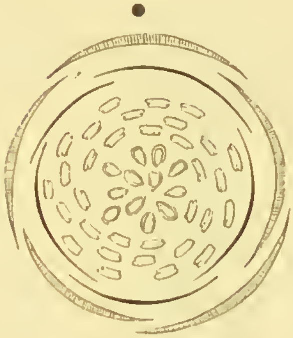


Fig. 1133.

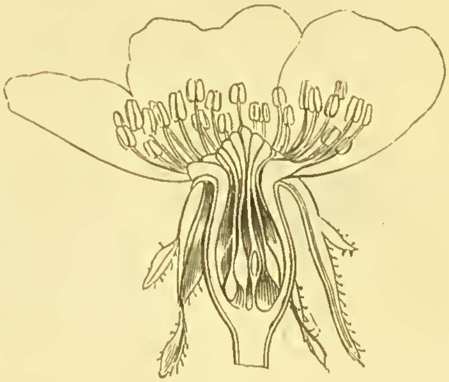


Fig. 1132. Diagram of the flower of a species of Rose, with five sepals, five petals, numerous stamens, and many distinct carpels.——*Fig.* 1133. Vertical section of the flower.

In the tribe *Spiræeæ* there are five cyclic carpels, and the fruit is five follicles. In some species the carpels unite together and form a simple gynœcium with free styles, thus approaching the *Pomeæ*. In the *Neuradeæ* they also unite with the receptacle.

In the tribe *Potentilleæ* the flower has a conspicuous epicalyx, generally held to be of stipular origin. The receptacle or thalamus becomes convex, but may be either dry, as in *Potentilla*, or succulent, as in *Fragaria* (the Strawberry). It bears a large number of achenes. *Geum* has a curiously bent style, forming a kind of hook which is instrumental in the dispersion of the fruits. *Dryas* has usually eight to ten petals.

In the tribe *Rubeæ* the structure of the fruit is much like that of the *Potentilleæ*, but the receptacle remains always dry and bears a collection of drupels. In the Raspberry (*Rubus Idæus*) these unite together and separate from the receptacle. In this tribe the flowers have no epicalyx. The plants frequently bear numerous prickles.

In the tribe *Roseæ* the fruit is a cynarrhodon; the achenes, which are very hard, line its sides. Like the last tribe, this includes a number of prickly plants.

Sub-order 4. *Sanguisorbeæ* or *Poterieæ.*—These are herbs or undershrubs. The flowers in some cases are diclinous, and the corolla is in many species wanting. The carpels are one to three, and the fruit is sunk in the tube of the thalamus, which becomes indurated as the seed ripens. *Alchemilla* has an epicalyx of four leaves, four sepals,

FIG. 1134.

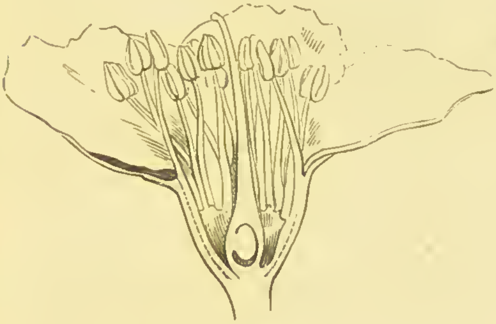
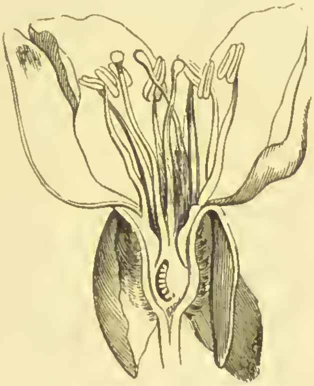


FIG. 1135.



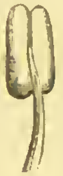


FIG. 1136.

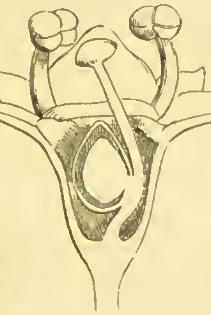


FIG. 1137.

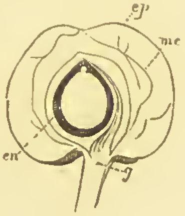


FIG. 1138.

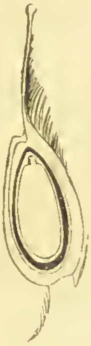


FIG. 1139.

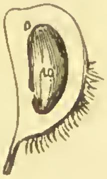


FIG. 1140.

Fig. 1134. Vertical section of the flower of the Peach (*Prunus* [*Amygdalus*] *persica*).——*Fig.* 1135. Vertical section of the flower of the Quince (*Pyrus Cydonia*).——*Fig.* 1136. Two-celled anther with part of the filament of a species of *Rubus*.——*Fig.* 1137. Vertical section of the flower of a species of *Alchemilla*.——*Fig.* 1138. Vertical section of the fruit (*drupe*) of the Cherry (*Prunus Cerasus*). *ep.* Epicarp. *me.* Mesocarp. *en.* Endocarp, within which is the seed with embryo.——*Fig.* 1139. Vertical section of an achænium of a species of Rose.——*Fig.* 1140. Vertical section of the ovary, *o*, of a species of *Rubus*, with the ovule, *ov*.

no petals, and four stamens alternating with the sepals. *Sanguisorba* has the four stamens opposite to the sepals; *Poterium* has twenty to thirty stamens.

Sub-order 5. *Pomeæ*.—The plants of this sub-order are trees or shrubs with simple leaves and caducous stipules. The flowers have generally twenty or twenty-five stamens arranged in three whorls.

There are one to five carpels, which unite with each other and with the succulent receptacular tube as already described. The carpels with the receptacle thus form a spurious fruit, on the summit of which the calyx persists.

There are two varieties of the fruit; in the Apple, Pear, Quince, &c., the endocarp is papery, while the rest of the pericarp is distinguishable with difficulty from the receptacular tube; in the Hawthorn, Medlar, &c., the endocarp is bony.

The arrangement of the stamens in Rosaceæ presents some rather singular features. Though frequently indefinite, they are not arranged spirally as in *Ranunculaceæ*. In the simplest forms, as in some members of the tribe *Poterieæ*, they are equal in number to the petals, and often alternate with them. In some of the Hawthorns the typical five constituting a single whorl, become ten by what has been called parapetalous multiplication. The ten form but one whorl, but are placed in pairs which are alternate with the petals. The paired arrangement is not at first very obvious, but measurement will show that the space between two stamens before each petal is rather wider than that between any two opposite to a sepal. In certain other species of *Cratægus*, and in *Nuttallia*, there are fifteen stamens, a whorl arising inside the whorl of five pairs, and its members being opposite the middle of each petal. In the *Pomeæ* there are in some cases twenty stamens, an additional whorl of five being intercalated opposite to the outer pairs. In the Pomeæ with twenty-five stamens, the second circle has ten stamens in pairs instead of five single ones. In some other species there are from thirty to fifty, probably in circles of ten each. The explanation given by Asa Gray, who has called attention to this peculiar arrangement, is that chorisis of the original prominences is the cause of the singular doubling of the numbers in the whorls, and that the increased number of the whorls is due to ordinary regular augmentation of circles. It has not, however, found acceptance by all botanists.

Order 2. CONNARACEÆ.—This is a small family of tropical shrubs with alternate pinnate leaves without stipules. The flowers are pentamerous, the stamens monadelphous, and the fruit a follicle. The seed is furnished with an aril.

Order 3. LEGUMINOSÆ.—The most characteristic feature of this order is the monocarpellary gynœcium, which has its ventral suture posterior. It develops usually into a pod or legume, from which the name of the order is derived. It is, however, in a few cases a follicle or a pyxis (*Trifolium*), or a berry or a drupe; in a few species it is a lomentum, and it is a nut in *Melilotus*. The plants of the order are trees, shrubs, or herbs, with usually compound stipulate leaves whose leaflets in some cases bear stipels, and with racemose inflorescences. The flowers are generally zygomorphic and pentamerous; the calyx has the odd sepal anterior, contrasting thus with the *Rosaceæ*; it is gamosepalous. The stamens vary in the different sub-orders. The seeds are exalbuminous in the British species.

Many plants of this order possess the peculiar property of being able to bring into combination and absorb the free nitrogen of the air. This is connected with a symbiotic association with a particular micro-organism, the symbiosis resulting in the development of peculiar tubercular bodies on the roots. The details of the fixation of the nitrogen have not at present been ascertained. Many plants of the order exhibit the possession of peculiar sensitiveness to contact and to changes in their environment. Nyctitropic movements are manifested by several. In some species, especially the Australian Acacias, the blade of the leaf does not persist, and the flattened petiole or phyllode takes on the function of the blade. *Lathyrus Nissolia*, an English species, also bears phyllodes. In *L. Aphaca* the whole axis of the leaf is transformed into a tendril, and the stipules become large and foliaceous.

There is a very close alliance between *Leguminosæ* and *Rosaceæ*; indeed it is difficult to find a character that absolutely distinguishes between them. The *Amygdaleæ* and *Chrysobalaneæ* approach those Leguminosæ whose fruit is a drupe. The *Spiræeæ*, like some other species of the latter order, bear follicles. The indefinite number of the stamens of most Rosaceæ is met with again in the tribe or sub-order *Mimoseæ*. The only constant feature of difference is the position of the unpaired sepal, which is anterior in Leguminosæ and posterior in Rosaceæ.

The Leguminosæ are divided into three sub-orders as under:—

Sub-order 1. *Papilionaceæ*.—All the British plants of the order belong to this group. It is marked by its conspicuously zygomorphic flowers with the peculiar æstivation of the corolla. The calyx is gamosepalous and persistent, in some cases almost bilabiate. The corolla consists of five petals, the posterior of which is the largest, and is in many species bent in the centre at nearly a right angle (*fig.* 1141). This is known as the *vexillum*, or *standard*. In its æstivation it covers the margins of the next two petals, the *alæ* or *wings*, and these in turn cover those of the two most interior, which are slightly attached to each other and form a boat-shaped body, the *carina* or *keel.* All these four petals are very irregular in shape. Their arrangement is shown in *fig.* 1145. There are ten stamens, which arise in two whorls; but by a displacement similar to that occurring in the Geraniaceæ their filaments come to be apparently on the same level, and are arranged in a few cases to form a continuous sheathing band round the pistil; this band extends halfway towards the anthers, and the upper half of each filament is free. In most cases only nine of the filaments are thus united and form a kind of trough round the pistil, the groove of which is uppermost and is roofed in by the tenth stamen. The trough usually contains honey. The stamens are thus monadelphous or diadelphous. In most cases all the filaments are approximately of a length, and the anthers are all crowded into the front part of the keel. In others the filaments of the two whorls are of different lengths, so that five anthers are distinctly in advance of the other five. In a few species, which are all foreign, the stamens are free. There is a solitary carpel which becomes in fruit a *legume* or *pod* and bears a row of ovules along its ventral suture. The seeds are exalbuminous, and the cotyledons large and fleshy.

FIG. 1141.

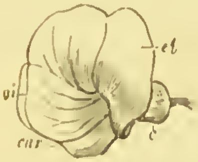


FIG. 1142.

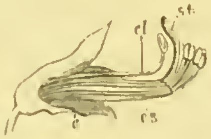


FIG. 1143.

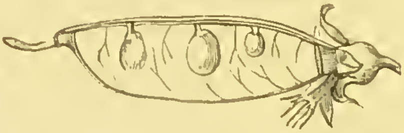


FIG. 1144.

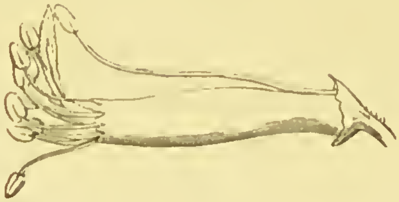


FIG. 1145.

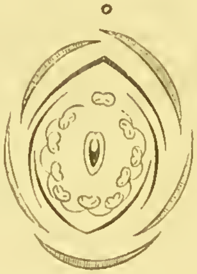


Fig. 1141. The flower of the Pea (*Pisum*). *el.* Standard or vexillum. *al.* Wings or alæ. *car.* Carina or keel enclosing the sporophylls. *c.* Calyx.——*Fig.* 1142. The sporophylls of the same surrounded by the calyx *c.* *cs.* Bundle of nine stamens. *el.* Solitary stamen. *st.* Style and stigma.——*Fig.* 1143. Legume of the same, with one valve removed.——*Fig.* 1144. Diadelphous stamens of the Sweet Pea (*Lathyrus odoratus*), surrounding the simple pistil. There are ten stamens, nine of which are united and one free.——*Fig.* 1145. Diagram of flower of *Lathyrus.*

The process of cross fertilisation in the Papilionaceæ is carried out by insects, chiefly bees. The pollen is shed from the anthers, usually into the apex of the keel, which is full of it. An insect alighting upon the wings and keel, which form a resting-place for it, causes by its weight a certain amount of the pollen to be squeezed out through the lip of the keel upon its under surface. When the insect visits a flower whose pollen has all been exhausted by repeated visitors, the stigma is protruded through the same aperture. In most cases the stigma is not mature or capable of pollination till the pollen has been discharged. There are many variations of detail in the mechanism, a full discussion of which is beyond our present limits. In *Sarothamnus* and some other genera the pollen is not shed into the keel, but the stamens are curled up and confined there, being released with a kind of explosion when an insect settles on the flower. The pollen is by the force of their elastic recoil shaken upon the insect in different but definite places, exactly where the stigma of the next flower visited will fall.

The stamens are free in the tribes *Sophoreæ* and *Podalyrieæ*; the monadelphous condition is met with in the British genera *Ulex*, *Genista*, *Sarothamnus*, *Ononis*. and *Anthyllis*.

Sub-order 2. *Cæsalpineæ*.—These plants have a zygomorphic flower, with an æstivation which is exactly the reverse of that of the Papilionaceæ, the posterior petal being small and most internal. They are mainly arborescent in habit. The zygomorphy is not so well marked as in the last sub-order; the calyx is gamosepalous and the stamens are free, and in many cases some of them are abortive. The fruit shows considerable

FIG. 1146.

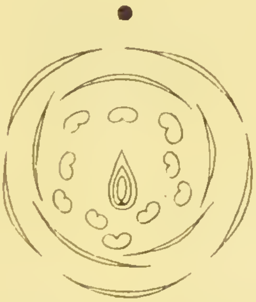


FIG. 1147.

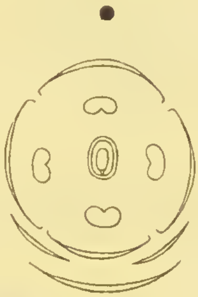


Fig. 1146. Diagram of the flower of one of the *Cæsalpineæ*.— *Fig.* 1147. Diagram of the flower of *Mimosa*.

variety, that of several species being indehiscent. The seeds in many cases are albuminous.

Sub-order 3. *Mimoseæ.*—In this sub-order the flowers are regular and actinomorphic; the stamens, normally ten, are in some genera fewer and in others indefinite. They protrude beyond the perianth, and may be either free or monadelphous. The inflorescence of some species is a capitulum. In several cases the seeds are albuminous.

Order 4. SAXIFRAGACEÆ.—The plants of this order are herbs which generally have alternate or spiral phyllotaxis. The leaves are exstipulate, but have a broad base. The inflorescence is as a rule cymose. The flower is often irregular in consequence of the suppression of some of its parts, the petals particularly being sometimes wanting. The typical flower of the order is 4—5-merous with obdiplostemony; it has generally two carpels, which are often partially or wholly inferior. The carpels are frequently united at their bases only, so that the ovary is unilocular below, but is bilocular above. The styles

FIG. 1148.

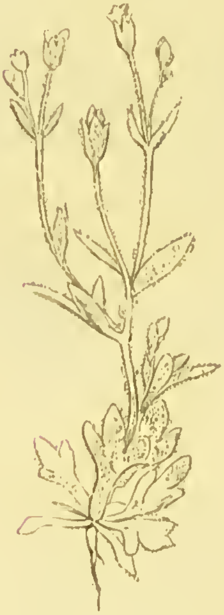


FIG. 1149.

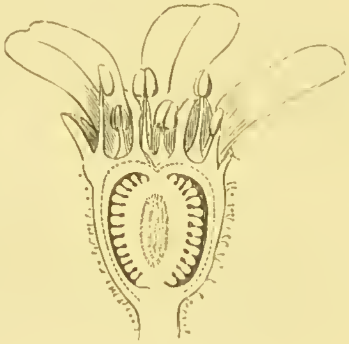


FIG. 1150.

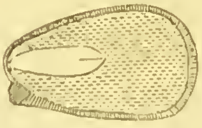


Fig. 1148. *Saxifraga tridactylites.* The leaves are trifid and wedge-shaped, and the flowers arranged in a cyme.—*Fig.* 1149. Vertical section of the flower.—*Fig.* 1150. Vertical section of the seed.

are divaricating. Some of the tribes have four to five carpels. The ovary is frequently inferior (*fig.* 1149) or partially so; in the latter case the receptacular tube leaves the carpels about halfway up their length. The seeds are albuminous.

The order is divided into several tribes as under:—

1. *Saxifrageæ.*—The British genera of this tribe are *Saxifraga* and *Chrysosplenium*. In the former the fruit is a 2-celled capsule, which opens along the ventral suture between the two styles. The latter has no corolla, and its capsule is 1-celled.

2. *Parnassieæ.*—The flowers in this tribe are perigynous and often actinomorphic. The ten stamens of the order are represented by the five stamens of the inner whorl, and the outer antipetalous whorl is replaced by five staminodes of peculiar form (*fig.* 1151). The pistil has from four to five carpels. The obdiplostemonous condition of the order must be borne in mind, as the staminodes really represent the properly inner whorl of the andrœcium.

FIG. 1151.

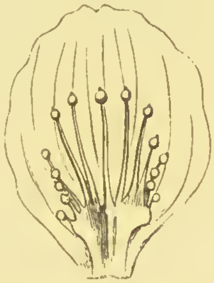


Fig. 1151. Petal of *Parnassia*, showing the antipetalous staminode.

3. *Francoeæ.*—A small tribe of South American herbs with no apparent stems. The flowers are tetramerous throughout, and the stamens are in four whorls of four each, two of them consisting of scaly staminodes.

4. *Escallonieæ.*—A family of South American shrubs with leathery glandular leaves. The flowers are pentamerous; but the ovary is often only 2-celled, and is crowned by a cone-shaped disc.

5. *Philadelpheæ.*—The flowers are actinomorphic, and the ovary is inferior. The stamens are in two whorls, in regular alternation with the other parts of the flower.

6. *Hydrangeæ.*—These resemble the last tribe, with which they are sometimes included. The stamens differ from those of the *Philadelpheæ* in being obdiplostemonous. The flowers of Hydrangea are arranged in a panicle, the marginal ones being sterile. In cultivation all become so.

7. *Cunonieæ.*—These plants are arborescent, and have opposite or whorled leaves with large interpetiolar stipules.

8. *Ribesieæ.*—The flowers of this tribe have only five stamens and an inferior bicarpellary ovary, which in fruit becomes a berry with two parietal placentæ.

Ribes Grossularia, the Gooseberry, and a few other species bear branched or unbranched prickles, which are emergences springing from the bases of the petioles. Several species are cultivated for their flowers or fruits.

Order 5. CRASSULACEÆ.—The plants of this order are herbs or shrubs, with entire or pinnatifid, succulent or fleshy, exstipulate leaves, often arranged in rosettes. The flowers are remarkable for their regular symmetry. They are isomerous, and as a rule diplostemonous. The number of leaves in each floral whorl is generally five, but may range between three and twenty. The stamens are frequently almost hypogynous. The carpels are opposite to the petals, and each bears a scale on its outer side. The fruit is in most cases a whorl of follicles, but a capsule is met with in the tribe *Diamorpheæ*. The ovules are numerous, and the seeds albuminous.

The order includes the two tribes *Crassuleæ* and *Diamorpheæ*.

Order 6. DROSERACEÆ.—A small order of plants which have the peculiar property of digesting the bodies of insects which alight upon their leaves. They are herbaceous plants, and generally inhabit boggy or marshy places, many of them growing upon masses of *Sphagnum*. The flowers are pentamerous, and the stamens are sometimes twice, thrice, or four times as numerous as the petals. They are almost hypogynous in their attachment, so much so indeed that many botanists place the order in the series Thalamifloræ, very near to the *Violaceæ*. The pistil is composed of three to five carpels, which form a capsular fruit with parietal placentation.

The plants of the order possess slightly acid and acrid properties. They are chiefly interesting from the peculiar irritability of the glands on their leaves. Thus, the leaves of the *Droseras* are fringed with stalked glands, which curve over and imprison any insects that alight upon the leaf-blade; the plant known as Venus's Flytrap (*Dionæa muscipula*), a native of North America, has 2-lobed leaves, each lobe furnished on its upper surface with three stiff hairs; these, when touched, cause the two lobes of the leaf to shut together face to face and enclose the object touching them. The glands in these plants secrete a viscid acid digestive fluid, so that insects which are imprisoned by them become ultimately dissolved and absorbed for their nourishment.

Order 7. HAMAMELIDACEÆ.—A small order of arborescent plants. The flower is tetramerous or pentamerous, the corolla sometimes absent, the stamens diplostemonous, but the antipetalous ones are represented by scaly staminodes. The ovary is more or less inferior, and forms a 2-celled capsular fruit.

Order 8. BRUNIACEÆ.—A small order of South African plants; they are heath-like shrubs with pentamerous flowers. The ovary is half inferior in some species, but in others superior.

Order 9. HALORAGACEÆ.—The plants of this order are small herbs or shrubs, and are generally of aquatic habit. The flowers are small, and in several cases diclinous. The symmetry is typically tetramerous, which is shown in *Myriophyllum*. The stamens are diplostemonous, and the ovary is inferior, generally consisting of four carpels. The plants of the order show a continuous degradation from the type; *Gunnera* has fairly regular dimerous symmetry; *Hippuris* has no corolla, and but a rudimentary calyx, a single stamen, and only one carpel.

The order is placed here by Bentham and Hooker, but many writers regard it as allied to the *Onagraceæ* of the next cohort. It resembles them in the tetramerous symmetry and the inferior ovary, but differs from them in having solitary pendulous albuminous seeds.

Fig. 1152.

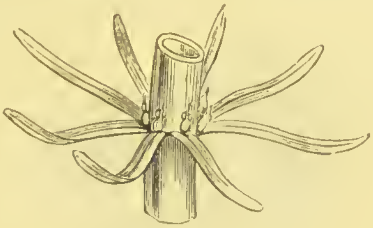


Fig. 1152. Whorled leafy bracts and solitary axillary flowers of Mare's Tail (*Hippuris vulgaris*).

Gunnera is peculiar in the anatomical structure of its stem, and in exhibiting curious cavities in its cortex, in which are found colonies of *Nostoc*.

Bentham and Hooker include the tribe *Callitrichcæ* in this order. Other botanists have included it in the *Euphorbiaceæ*. The flowers resemble those of *Hippuris* in their simplicity, but they have an ovary which is bilocular or spuriously quadrilocular, and contains four ovules.

Cohort 2.—*Myrtales.*

The leaves are in most cases simple and opposite; the flowers are cyclic, and either epigynous or perigynous; there are two whorls of stamens, which are often obdiplostemonous; the pistil is syncarpous, the style undivided, and the placentation usually axile; the seeds are without endosperm.

Order 1. MYRTACEÆ.—The plants of this order are arborescent, and have well-marked vegetative characters. Their leaves are opposite, exstipulate, entire; somewhat leathery in texture, and having a vein running just within their margins. They are plentifully supplied with reservoirs of etherial oil, which, when looked at by transmitted light, give the leaves the appearance of being studded with pellucid dots. In this respect they resemble the *Rutaceæ* and the *Hypericaceæ*. The flowers are regular; the perianth is 2-seriate, the calyx and corolla having the same number of leaves, usually four or five. The stamens are often very numerous (*fig.* 1153), the number arising from branching of the original prominences, which are usually, though not always, antipetalous. Some species have two whorls of unbranched stamens, which are obdiplostemonous. The pistil is composed of two to five carpels, which are coherent and are sunk in a receptacular tube, so that the ovary is inferior. The styles are coherent through their whole length. There are sometimes numerous seeds. There is a good deal of variety in the fruit, but a berry is frequently found. The placentation may be axile or parietal.

Fig. 1153.

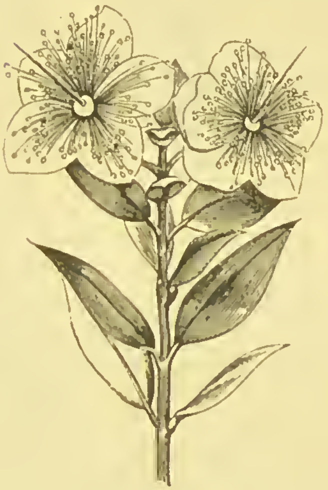


Fig. 1154.

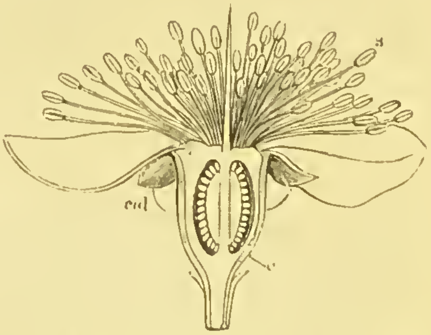


Fig. 1153. Flowering branch of the common Myrtle (*Myrtus communis*). —*Fig.* 1154. Epigynous flower of Myrtle.

The order includes the following tribes:—

1. *Myrteæ*, with baccate or drupaceous fruit. The young flower-buds of *Eugenia caryophyllata* form the spice known as Cloves.

2. *Leptospermeæ.*—This tribe is chiefly Australian and West Asian. The fruit is a capsule. The Australian Gum trees form the genus *Eucalyptus*. They are sometimes of gigantic size, reaching a height of nearly 500 feet. The arrangement of the leaves in the adult plants is peculiar, as they present their edges instead of their surfaces to the stem. In some genera the floral axis continues to grow after flowering.

3. *Lecythideæ.*—This is an American group, with zygomorphic flowers and leaves without oil glands. The fruit is large and woody, and dehisces in many cases by a kind of lid. *Bertholletia*, the Brazil-nut, belongs to this tribe.

4. *Chamælaucieæ.*—This tribe is exclusively Australian; the plants are heath-like, with evergreen dotted leaves and a pappus-like

calyx. They have a 1-celled ovary, and their fruit is a 1-seeded nut.

5. *Paniceæ* or *Granateæ.*—The plants of this group are confined to southern Europe and western Asia. The leaves have not the glands nor the marginal veins of the typical Myrtaceæ. The fruit is the so-called *balausta*, which consists of two whorls of carpels, one above the other (*fig.* 1155). The inner whorl has three carpels, and the outer five. During the growth of the wall of the ovary these become inverted, so that the inner whorl becomes the lowest. The seeds are attached to the angles of the carpels.

Tribes 3, 4, and 5 are by some botanists considered to be Natural Orders.

FIG. 1155.

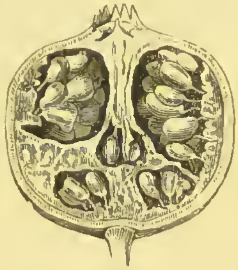


Fig. 1155. Vertical section of fruit of Pomegranate.

Order 2. RHIZOPHORACEÆ.—This is an order of tropical trees or shrubs which form the so-called Mangrove swamps, growing as they do by the banks of rivers and by sea-shores. Aerial roots are formed on the stems. The seeds are *viviparous*, that is, they germinate before they are detached from the tree; the embryo puts out a long strong radicle: when it is cast off from the plant it drops into the mud, which the radicle penetrates, and the seedling becomes anchored and continues its growth. The cotyledon is usually left in the fruit, so that the seedling or embryo which falls consists of the radicle and hypocotyl.

Order 3. COMBRETACEÆ.—A tropical order of arborescent habit; some of the plants are lianes. The flowers have a 1-celled ovary, and the fruit is indehiscent.

Order 4. MELASTOMACEÆ.—This is a large tropical order including about 2,000 species, and found most abundantly represented in South America. The plants are trees, shrubs, or herbs, with opposite or whorled simple leaves, most of which have several curved veins proceeding from their base to their apex. They have no oil glands. The flowers are either tetramerous or pentamerous, and the stamens are in two whorls. The stamens are bent in the bud; and each anther is pointed at its apex, and bears two auriculate appendages at its base. It opens by either one or two pores. The fruit may be dry or succulent; in the latter case the calyx is adherent to it.

Order 5. LYTHRACEÆ.—The plants of this order are herbs, shrubs, or trees, with sometimes square stems, simple entire leaves, without stipules as a rule, though very small ones are occasionally found. The flowers are 6-merous and perigynous.

The calyx in most cases takes the form of six small free teeth on the top of a tubular receptacle, and alternating with them in some species are six teeth of an epicalyx; the tube is generally rather strongly ribbed. The petals are inserted on the top of this receptacular tube. The stamens are typically in two whorls, but the inner may be wanting. The pistil is free at the bottom of the tube, and consists of from two to six carpels, which are syncarpous, and, when mature, form a capsular fruit with axile placentation.

Lythrum Salicaria, the Purple Loosestrife, is a common plant in England, growing generally in ditches. It is remarkable for its trimorphic flowers. Its two whorls of stamens have filaments of different lengths, and consequently the anthers stand at different heights in the flower. The styles also vary in length. There are thus three types of flower; in one the stamens are long and short, and the style is of intermediate length (*fig.* 1156); in another the style is short and the stamens are long and of median length; in a third the style is long and the stamens median and short. In *Cuphea* the flower is zygomorphic, the receptacle bearing a posterior spur.

FIG. 1156.

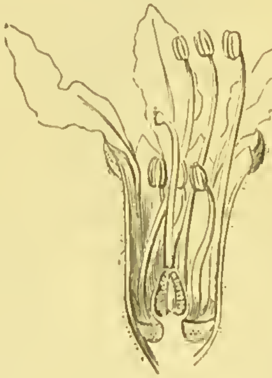


FIG. 1157.

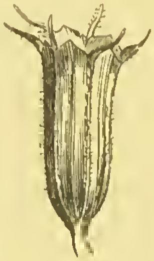


Fig. 1156. Vertical section of the flower of the Purple Loosestrife (*Lythrum Salicaria*).——*Fig.* 1157. Receptacular tube of the same, bearing the calyx.

Order 6. ONAGRACEÆ.—The plants of this order are herbs or shrubs, many of them growing by the sides of ditches or in marshy places. The leaves may be opposite or alternate, are always simple, and are generally without stipules. The flowers are regularly dimerous or tetramerous, and usually obdiplostemonous, but the antipetalous whorl of stamens is sometimes suppressed. The anthers are frequently septated. The pollen is triangular. The ovary is inferior, with axile placentation; it is usually 4-celled, but is 2-celled in Circæa, which has a dimerous flower throughout. The fruit is a capsule in the British genera, but is a berry in *Fuchsia*. In *Trapa* it is drupaceous.

FIG. 1158.

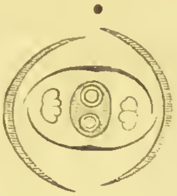


FIG. 1159.

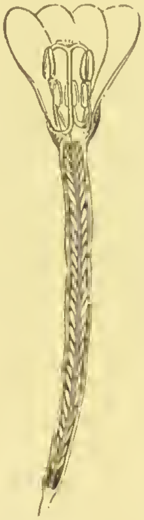


Fig. 1158. Diagram of the flower of *Circæa*.
Fig. 1159. Vertical section of the flower of a species of Willow-herb (*Epilobium*).

Epilobium is the principal British genus. It has an elongated capsule (*fig.* 1159), and the seeds have a tuft of hairs attached to the chalazal end. *Circæa* has dimerous flowers. Some of the exotic genera have zygomorphic flowers. *Trapa* has a drupaceous fruit which is crowned by four hornlike bodies, which are the persistent sepals.

Cohort 3.—*Passiflorales.*

The plants of this group have sometimes diclinous flowers; the gynœcium is syncarpous, and the placentation is parietal. In some the ovary is spuriously 3-celled. The stamens may be indefinite, or may be in one or in two whorls. The seeds may be albuminous or exalbuminous.

Order 1. PASSIFLORACEÆ.—The plants of this order are chiefly herbs which climb by means of simple or branched tendrils. They have alternate stipulate leaves, and large showy regular flowers which are pentamerous as far as the stamens, and have three carpels. Between the corolla and stamens there are several filamentous processes, which form a kind of corona. These are often variously united together, and are frequently petaloid and coloured. The sporophylls are often raised upon a gynophore. The stamens are sometimes monadelphous.

and are antipetalous. The seeds are arillate, and are borne in a 1-celled succulent fruit, which in some species is edible.

The morphology of the tendrils in this order and in the nearly related *Cucurbitaceæ* has been much discussed. The tendrils arise from the stem by the side of the petioles. One hypothesis is that they are stipular; the leaf is supposed to have normally a pair of stipules, of which one has been suppressed and the other transformed into the tendril. Another view attributes to them a peduncular origin. The flowers are axillary, and it has been suggested that one of the flower stalks becomes modified and adnate to the leaf stalk, and so appears as the tendril. Another view is that the latter is an extra-axillary branch arising at the side of the leaf and not in its axil. A fourth hypothesis was put forward by Naudin; according to this a branch arose from the axil of the leaf, but in the case of a simple tendril became completely merged with the petiole or with the stem, and grew no further. The only sign of this branch is one leaf which it bears on one side, but which does not take the form of a leaf, but is reduced to a midrib, which is the tendril. The compound tendrils are formed by the elongation of the branch, which bears several leaves modified to form the tendril-branches. Payer advanced a fifth hypothesis, which was that the tendril is due to a splitting of the petiole. The bundles of the latter are normally three. Payer suggested that the central one passes in the direct line to the petiole, while the others diverge and again unite, forming the tendril. A sixth view is the interpretation of Braun and Wydler, which has been adopted by Eichler. They held that the flower and its peduncle represent the axillary branch, the tendril by its side answers to one of the bractlets, that on the other side being suppressed, while the supernumerary branch springs from the axil of the tendril. This makes the tendril to be a simple leaf, of which its branches are the ribs. Gray has criticised this view adversely, pointing out that the divisions of the tendril are developed in a spiral order, and in vigorous growths occupy different heights on the tendril-axis.

Order 2. SAMYDACEÆ.—A small order of tropical plants bearing evergreen stipulate leaves with round or linear transparent glands.

Order 3. LOASACEÆ.—A small order of American herbs with stiff hairs or stinging glands. The flowers are regular, and bear two whorls of stamens which are much branched. The antipetalous ones form groups or phalanges of perfect stamens, while those in front of the sepals become petaloid staminodes. The ovary is inferior.

Order 4. TURNERACEÆ.—A small order of plants confined to South America and the West Indies. The flowers are pentamerous, the fruit is a capsule, and the seeds are furnished with a lateral caruncle.

Order 5. Datiscaceæ.—A small tropical order having insignificant flowers which are diœcious. They have no corolla. In some species the ovary is open at the top. It is inferior, with parietal placentation.

Order 6. Cucurbitaceæ.—The plants of this order are all herbaceous, and most of them climb by means of tendrils. The latter are situated by the side of the petioles, and may be either simple or branched. In the axil of the leaf a vegetative bud and a floral axis both occur. The arrangement is thus much the same as in the Passifloraceæ, under which order a discussion of the morphology of the parts has already been given. The flowers are regular, diclinous, and pentamerous; the sepals are narrow and pointed; the corolla is in some cases gamopetalous, in others the petals are free. The corolla is epigynous, and the stamens are adherent to the petals. Both arise from a cup-shaped development of the receptacle above the ovary. The stamens are five, but appear to be three (*fig.* 1161), in consequence of four of them cohering in two pairs. The anthers are sinuous (*fig.* 1160), and according to some botanists each represents only half an anther, the other half not being developed. In *Cucurbita* all the stamens are united into a column. Sometimes the rudiments of a gynœcium are present in the staminate flowers. The carpels are generally three in number and are syncarpous and inferior, forming in fruit either a pepo or a berry. The style is short and thick, and bears a 3-lobed stigma. The pistillate flowers frequently contain rudiments of the abortive stamens. The seeds are exalbuminous.

Fig. 1160.

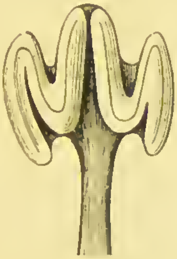


Fig. 1161.

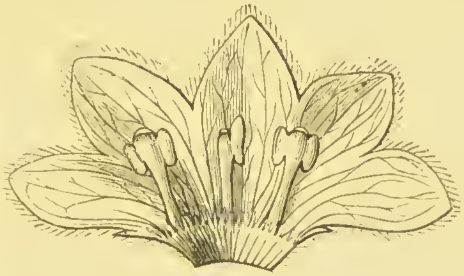


Fig. 1160. Stamen of *Citrullus*, with sinuous anther. —*Fig.* 1161. Flower of *Citrullus* cut open and spread out. After Warming.

The fruit is often described as trilocular with projecting axile placentas (*fig.* 1162). The structure has been explained on two theories: according to the first, each placenta arises on the margin of a carpellary leaf, and passes inwards towards the centre of the ovary, becoming soon reflexed and adnate to itself; after it has returned nearly to the margin, it turns at almost a right angle and bears the ovules. On the second theory, the placentas from the two margins of each carpel grow in and meet, then turn back and bear the ovules. In both cases the original partitions are obliterated. On the first hypothesis the forked placenta is opposite to the ventral, and on the second to the dorsal suture of the carpellary leaf.

Fig. 1162.

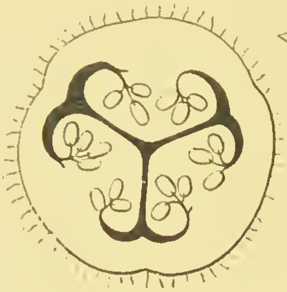


Fig. 1163.

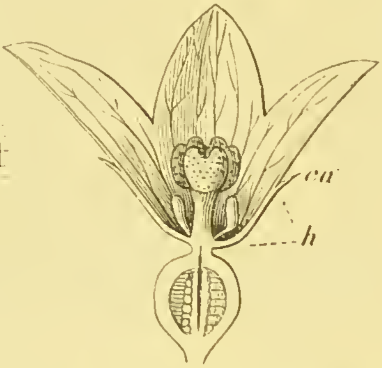


Fig. 1162. Transverse section of ovary of *Citrullus*.——*Fig.* 1163. Female flower of *Citrullus* in longitudinal section. *h*. Receptacle. *ca*. Calyx. After Warming.

The Cucurbitaceæ have been divided by Bentham and Hooker as follows:—

Series 1. PLAGIOSPERMEÆ.—Ovules horizontal.
Series 2. ORTHOSPERMEÆ.—Ovules erect or ascending.
Series 3. CREMOSPERMEÆ.—Ovules pendulous.

An acrid bitter purgative property is the chief characteristic of the plants of this order; this is possessed more or less by all parts of the plant, but it is especially evident in the pulp surrounding the seeds; the seeds themselves are, however, usually harmless. In some plants this acridity is so concentrated that they become poisonous; while in other cases, especially those under cultivation, it is so diffused that their fruit is edible.

Bryonia is the only British genus. *Ecbalium* is the Squirting Cucumber; when ripe the fruit is distended with an acrid juice, and if touched it ruptures at the base, and the seeds, together with the juice and pulp, are violently ejected at the point of rupture.

Order 7. BEGONIACEÆ.—The plants of this order are herbs or undershrubs with succulent stems and oblique or asymmetrical leaves, with large membranous stipules which soon fall off. The inflorescence is cymose; the flowers are diclinous and monœcious. The staminate flowers have usually four perianth leaves in two whorls, and numerous stamens which are most frequently united into a column; the pistillate flowers have five epigynous perianth leaves showing spiral phyllotaxis, and an inferior ovary with three cells, surmounted by three bifid styles. The sides of the ovary are winged. The placentation is axile.

Cohort 4.—*Ficoidales.*

The plants are characterised by usually possessing a fleshy stem, which is in some cases a phylloclade, and in others bears fleshy or succulent simple leaves without stipules; the flower is epigynous or perigynous, and the stamens generally numerous.

Order 1. CACTACEÆ.—These plants are remarkable for the curious appearance of their stems, which are fleshy and, in a few cases only, ultimately become woody. They are all phylloclades, being flattened in *Cereus*, compressed in *Opuntia*, thick and almost ovoid in *Echinopsis*, and in other genera variously branched and jointed. The leaves are usually abortive, being replaced by spines, which are arranged in various ways upon the phylloclades. In some genera they are

FIG. 1164.

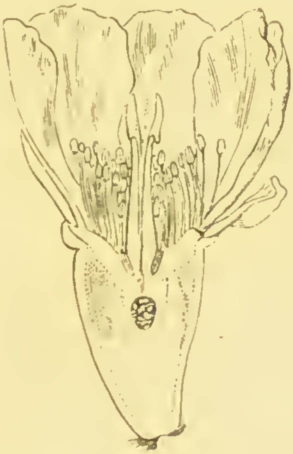


FIG. 1165.

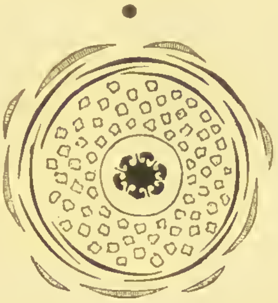


Fig. 1161. Section of the flower of the Prickly Pear (*Opuntia vulgaris*).——*Fig.* 1165. Diagram of the flower of the same.

not less than 50 or 60 feet in height, in others dwarfed and stunted. Some are climbers, using roots for that purpose; others are epiphytes. In *Pereskia* foliage leaves occur, which are thick and fleshy. The flowers are acyclic; the petals are free, or united at their bases; the stamens are indefinite and attached to the bases of the petals; the pistil is syncarpous; the ovary is inferior, 1-celled, with several parietal placentas.

Order 2. MESEMBRYANTHACEÆ or FICOIDACEÆ.—These are succulent plants, with thick fleshy stems and leaves without stipules. The flower has a perianth which is usually sepaloid; the second whorl may take the form of stamens, which are often very numerous through branching of the original protuberances, or may become partly petaloid. The third whorl consists of the carpels. The three whorls thus constituted are in regular alternation. In the tribe *Mesembryanthemeæ* the ovary is inferior; in the rest of the order it is superior. The fruit is a capsule.

Bentham and Hooker place the tribe *Mollugineæ* of the *Caryophyllaceæ* in this order.

Cohort 5.—*Umbellales.*

The plants of this group have their flowers arranged in umbels; they are generally regular and actinomorphic, but those on the outside of the umbels are in some cases radiant and zygomorphic. The calyx is inconspicuous, often forming only a rim round the top of the inferior ovary. The latter is bicarpellary, 2-celled, with a single ovule in each cell. The styles are surrounded at their bases by an epigynous disc. The seeds are albuminous.

Order 1. UMBELLIFERÆ.—The plants of this order are usually herbs which have hollow stems, crossed by a species of diaphragm at each node; the leaves are spirally arranged, and have a broad base from which rises a remarkable inflated sheath which partially surrounds the stem. The leaves in most cases are very much divided, being bi- or tri-pinnate, with ultimate pinnatifid leaflets. Simple leaves are rare, but occur in the genera *Hydrocotyle* and *Bupleurum*. The flowers are arranged in either simple or compound umbels. Each umbel may be surrounded by bracts which form an involucre. When the latter is at the base of a compound umbel it is termed a *general* involucre; when at the base of the simple umbels which are the terminations of the pedicels of the compound umbel.

it is said to be a *partial* involucre. Either the general or the partial involucres may be absent.

The flowers are regular and usually actinomorphic, but radiant flowers occur on the margins of some of the umbels. These become zygomorphic through the anterior petal being enlarged, while the posterior two, which face towards the centre of the umbel, remain small. The calyx is superior and generally surrounds the summit of the ovary as a mere rim ; in some species the separate sepals, five in number, occur in the form of small teeth. The petals are free, usually white or yellow, occasionally blue ; they have a short claw and an incurved apex which gives them the appearance of being obcordate. The

Fig. 1166.

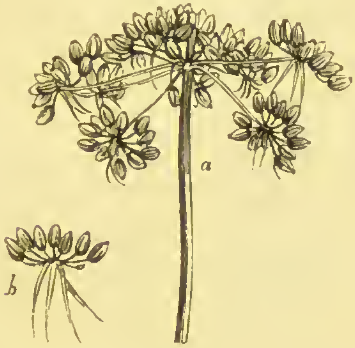


Fig. 1167.

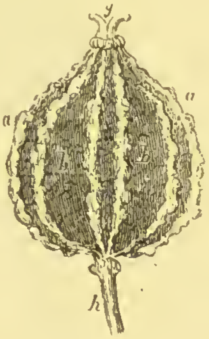


Fig. 1168.

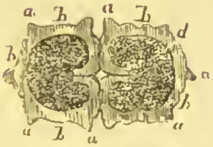


Fig. 1169.

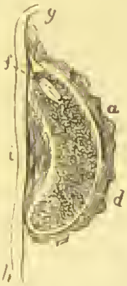


Fig. 1166. *a.* General umbel of Fool's Parsley (*Æthusa Cynapium*) in fruit. *b.* One of the umbellules, showing the 3-leaved unilateral pendulous involucel.——*Fig.* 1167. A side view of the ripe fruit of Hemlock (*Conium maculatum*).——*Fig.* 1168. Transverse section of the fruit of the same.——*Fig.* 1169. Vertical section of one of the halves (*mericarps*) of the same fruit. The letters refer to the same parts in the last three figures. *a.* Ridges. *b.* Channels. *d.* Albumen. *f.* Embryo. *g.* Remains of the styles. *h.* Axis. *i.* Prolonged axis or carpophore.

stamens are inserted on the margin of an epigynous disc which surrounds the bases of the two styles and is sometimes called a *stylopode.* The ovary is inferior, bicarpellary, and syncarpous. It has two loculi, with a single seed in each.

The fruit is very characteristic of the order. It is a schizocarp, technically termed a *cremocarp*, which splits when ripe into two mericarps that remain attached to a common stalk, or *carpophore.* Each mericarp is an indehiscent 1-seeded body whose dorsal surface is traversed by ridges or projections (*fig.* 1167). Three of these are on the free surface of the mericarp, and two others are at the angles of the commissure or line of separation between the two mericarps (*fig.* 1168). These five ridges each contain a vascular bundle, and are known as the *primary* ridges. In some species these are absent, but there are instead four so-called *secondary* ridges, which occur in the spaces between the places where the primary ones should be. In other species all nine are present on each mericarp, which then has a very rough appearance. In the wall of the mericarps oil glands or reservoirs frequently occur. Their distribution and their numbers vary in different species, but few are without them. They are generally termed *vittæ.*

FIG. 1170.

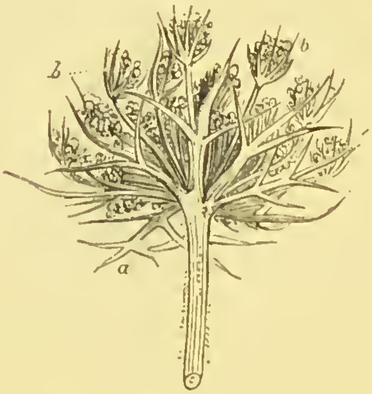


Fig. 1170. Compound umbel of the Carrot (*Daucus*). *a.* General involucre. *b, b.* Partial involucres.

The determination of the genera depends very largely on the details of the arrangements, peculiarities of the ridges, and the vittæ.

The seeds are albuminous, and the embryo is minute.

The divisions of the order depend primarily on the form of the endosperm. It has been divided into three sub-orders, but these are by no means well defined. They are as follows: —

Sub-order 1. ORTHOSPERMEÆ.—Endosperm not curved.

Sub-order 2. CAMPYLOSPERMEÆ.—Endosperm rolled inwards at the margins, and presenting a vertical furrow on its face.

Sub-order 3. CŒLOSPERMEÆ.—Endosperm with the base and apex curved inwards towards the axis.

By Bentham and Hooker this order has been divided as follows:—

Series 1. HETEROSCIADIEÆ.—Umbels generally simple or very irregularly compound, or the inflorescence is a capitulum. Vittæ absent or obscure.
Series 2. HAPLOZYGIEÆ.—Umbels compound. Primary ridges of fruit alone conspicuous. Vittæ usually, but not always, obvious.
Series 3. DIPLOZYGIEÆ.—Umbels usually compound. Fruit with both primary and secondary ridges generally well marked.

The Umbelliferæ are chiefly natives of the northern parts of Europe, Asia, and America. Many occur, however, in the southern hemisphere. They are rare in tropical regions except upon the mountains, where they are by no means uncommon. There are about 1,400 species. In Great Britain the order is represented by 40 genera.

Some of them are extremely poisonous, among which may be mentioned *Conium maculatum*, the Hemlock, *Œnanthe crocata*, the Water-Dropwort, *Æthusa Cynapium*, the Fool's Parsley, *Cicuta virosa*, the Water-Hemlock. Some, on the other hand, furnish certain of our vegetables, *e.g.* the Carrot, Parsnip, Celery. Many of them are aromatic, especially the Caraway and Dill. A few depart from the typical vegetative characters of the order: *Hydrocotyle* and *Bupleurum* have entire leaves; *Eryngium*, the Sea Holly, has a capitulum for its inflorescence; *Crithmum*, the Samphire, has fleshy leaves with lanceolate leaflets; *Fœniculum*, the Fennel, bears tripinnate leaves, which have neither axis nor branches winged. *Astrantia* has an umbel of minute flowers surrounded by an involucre composed of large, sometimes coloured bracts.

Order 2. ARALIACEÆ.—The plants of this order are trees or shrubs with simple or compound leaves, somewhat sheathing at their bases. The flowers are in umbels or capitula, and are pentamerous except as to the pistil, which may have from two to many carpels. The ovary is inferior, and the fruit is a drupe or a berry. The petals are deciduous, and have a well-marked valvate æstivation.

FIG. 1171.

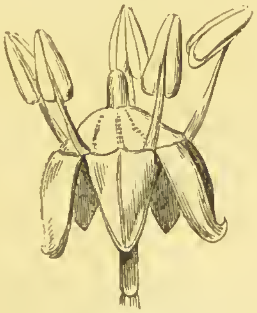


Fig. 1171. Flower of the common Ivy (*Hedera Helix*, *Araliaceæ*).

Order 3. CORNACEÆ.—These are shrubby plants with generally opposite exstipulate leaves which are not sheathing at their bases. The flowers are tetramerous, and are collected into compact inflorescences which may be corymbs, umbels, or capitula. The ovary is inferior, 2-celled; the fruit is a berry or a drupe; in the latter case the stone may be 1—4-celled, or there may be two free stones.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 3. Calycifloræ.

1. Flowers with more than 20 stamens.

A Ovary wholly superior.
  a. *Leaves without stipules.*
    1. *Carpels more or less distinct (at least as to the styles); or solitary.*
      Stamens distinctly perigynous. Ovules suspended, erect, or ascending . . . *Rosaceæ (part).*
    2. *Carpels wholly combined (at least as to the ovaries).*
      Sepals more than 2, united into a tube.
        Ovary with axile placentas . . . *Lythraceæ (part).*

  b. *Leaves with stipules.*
    1. *Carpels more or less distinct (at least as to the styles); or solitary.*
      Calyx with the odd lobe inferior. Stamens somewhat hypogynous . . . *Leguminosæ (Mimoseæ).*
      Calyx with the odd lobe superior. Stamens distinctly perigynous . . . *Rosaceæ.*
    2. *Carpels wholly combined (at least as to the ovaries).*
      Leaves with circinate vernation. Placentas parietal . . . . *Droseraceæ.*

B. Ovary inferior, or partially so.
  a. *Leaves without stipules.*
    1. *Placentas parietal.*
      Petals definite in number, distinct from the calyx . . . . *Loasaceæ.*
      Petals indefinite in number, gradually passing into the sepals . . . . . *Cactaceæ.*
    2. *Placentas in the axis.*
      Leaves with transparent dots.
        Ovary 1-celled . . . . . *Myrtaceæ (Chamælaucieæ).*
        Ovary with more than 1 cell . . . *Myrtaceæ (Myrteæ).*
      Leaves without dots.
        Petals very numerous . . . . *Mesembryanthaceæ.*

Petals definite in number.	
Petals narrow and strap-shaped .	*Cornaceæ (Alangieæ).*
Petals roundish and concave.	
Styles united .	*Myrtaceæ (Barringtoneæ).*
Styles distinct	*Saxifragaceæ (Philadelpheæ).*
b. *Leaves with stipules.*	
1. *Carpels more or less distinct, or solitary* .	*Rosaceæ (part).*
2. *Carpels wholly combined (at least as to the ovaries).*	
Leaves opposite	*Rhizophoraceæ.*
Leaves alternate.	
Placentas axile	*Myrtaceæ (Lecythideæ).*
Placentas parietal .	*Samydaceæ (Homalideæ).*

2. Flowers with fewer than 20 stamens.

A. Ovary wholly superior.	
a. *Leaves without stipules.*	
1. *Carpels more or less distinct, or solitary.*	
Carpels with hypogynous scales.	
Each carpel having 1 scale . . .	*Crassulaceæ.*
Each carpel having 2 scales . .	*Saxifragaceæ (Francoeæ).*
Carpels without hypogynous scales.	
Carpels solitary, or all but 1 imperfect.	
Leaves without dots.	
Ovules collateral, ascending, sessile .	*Connaraceæ.*
2. *Carpels more or less combined (at least by their ovaries).*	
Placentas parietal.	
Flowers with a ring or crown.	
Flowers unisexual	*Passifloraceæ (Papayeæ).*
Flowers hermaphrodite . . .	*Passifloraceæ (Malesherbieæ).*
Flowers without a ring or crown . .	*Turneraceæ.*
Placentas in the axis.	
Styles distinct to the base.	
Carpels each with 1 hypogynous scale .	*Crassulaceæ.*
Carpels without hypogynous scales	*Saxifragaceæ (part).*
Styles more or less combined.	
Calyx imbricate. Ovules suspended .	*Bruniaceæ.*
Calyx valvate.	
Leaves simple. Calyx tubular . .	*Lythraceæ.*

b. *Leaves with stipules.*
  1. *Carpels distinct, or solitary.*
    Fruit leguminous; odd lobe of the calyx inferior . . . . *Leguminosæ.*
    Fruit not leguminous; odd lobe of the calyx superior . . . . *Rosaceæ.*
  2. *Carpels more or less combined (at least by their ovaries).*
    Placentas parietal.
      Flowers with a ring of appendages . . *Passifloraceæ.*
    Placentas in the axis.
      Styles distinct to the base.
        Petals conspicuous.
          Leaves opposite . . . . { *Saxifragaceæ (Cunonieæ).*
          Leaves alternate . . . . { *Saxifragaceæ (part).*

B. Ovary inferior, or partially so.
  a. *Leaves without stipules, or with cirrhose appendages.*
    Placentas parietal.
      Flowers completely unisexual. Gamopetalous . . . . *Cucurbitaceæ.*
      Flowers hermaphrodite or polygamous. Petals distinct . . . . { *Saxifragaceæ (Ribesieæ).*
    Placentas in the axis.
      Flowers in umbels, or capitula.
        Styles 2 . . . . *Umbelliferæ.*
        Styles 3 or more . . . . . *Araliaceæ.*
      Flowers not in umbels.
        Carpel solitary.
          Petals strap-shaped, reflexed . . { *Cornaceæ (Alangieæ).*
          Petals oblong.
            Cotyledons convolute . . . . *Combretaceæ.*
            Cotyledons flat . . . . . *Haloragaceæ.*
        Carpels 2 or more, divaricating at the apex.
          Leaves alternate. Herbs . . { *Saxifragaceæ (part).*
          Leaves opposite. Shrubs . . { *Saxifragaceæ (Hydrangeæ).*
        Carpels 2 or more, not divaricating, combined.
          Calyx valvate, or the limb obsolete.
            Stamens alternate with the petals if isomerous.
              Albumen none. Ovules horizontal or ascending . . . *Onagraceæ.*

Albumen present. Ovules pendulous . . . . . . *Haloragaceæ*.
Albumen abundant. Flowers conspicuous . . . . . *Cornaceæ*.
Calyx not valvate.
Stamens doubled downwards. Anthers with appendages. Leaves ribbed *Melastomaceæ*.
Stamens only curved. Anthers short.
Leaves dotted . . . . . *Myrtaceæ*.
Leaves not dotted.
Seeds very numerous, minute *Saxifragaceæ* (*Escallonieæ*).
Seeds few . . . . . *Bruniaceæ*.

b. *Leaves with stipules.*

Placentas parietal.
Stipules cirrhose. Gamopetalous . . *Cucurbitaceæ*.
Stipules deciduous. Petals distinct . *Samydaceæ* (*Homalieæ*).
Placentas in the axis.
Stamens, if equal to the petals, alternate with them.
Leaves opposite . . . . . . *Rhizophoraceæ*.
Leaves alternate . . . . . . *Hamamelidaceæ*.

Although it generally happens that the Calycifloræ have dichlamydeous flowers, polypetalous corollas, and perigynous or epigynous stamens, yet many exceptions occur, which should be particularly noted by the student. Thus, we find apetalous plants in the *Leguminosæ*, *Rosaceæ*, *Saxifragaceæ*, *Crassulaceæ*, *Hamamelidaceæ*, *Haloragaceæ*, *Rhizophoraceæ*, *Combretaceæ*, *Samydaceæ*, *Loasaceæ*, *Datiscaceæ*, *Mesembryanthaceæ*, *Araliaceæ*, *Myrtaceæ*, *Lythraceæ*, *Onagraceæ*, *Passifloraceæ*. Gamopetalous corollas occur in some *Cucurbitaceæ*, *Crassulaceæ*, *Droseraceæ*, *Bruniaceæ*, *Melastomaceæ*, *Turneraceæ*, *Cactaceæ*, *Araliaceæ*. In some Calycifloræ, again, the stamens are wholly or in part hypogynous or nearly so, as in some *Connaraceæ*, *Leguminosæ*, *Saxifragaceæ*, *Crassulaceæ*.

Diclinous flowers occur as a rule in *Cucurbitaceæ*, and sometimes in *Rosaceæ*, *Passifloraceæ*, *Haloragaceæ*, *Combretaceæ*, *Cornaceæ*, *Hamamelidaceæ*, and *Araliaceæ*.

Synopsis of the British Natural Orders in the Series Calycifloræ.

A. Corolla polypetalous. Ovary superior.
1. Ovaries many, distinct or united, each with a style; or solitary with 1 lateral placenta.
Corolla regular.
Sepals combined below.
Stamens equal to or double the number of the petals; no stipules . . . *Crassulaceæ.*
Stamens 20 or more, perigynous. Leaves stipulate . . . . . . *Rosaceæ.*
Corolla irregular.
Leaves with stipules. Stamens mono- or diadelphous . . . . *Leguminosæ.*
2. Ovary solitary, with parietal placentation.
Corolla regular. Sepals equal, free, imbricate.
Stamens 5 . . . . *Droseraceæ.*
3. Ovary solitary, with central placentas.
Calyx valvate in the bud.
Stamens inserted in the calyx tube below the petals . . . . *Lythraceæ.*

B. Corolla polypetalous, ovary partly or wholly inferior.

1. Ovary 1-celled. Placentas 2, parietal. Ovules numerous . . . . *Ribesiaceæ.*
2. Ovary 2—many-celled. Placentas central.
Stamens as many as the petals, or twice as many.
Petals imbricate in the bud.
Petals 5. Stamens 5. Flowers in umbels *Umbelliferæ.*
Petals 4—5. Ovary only partially inferior. Capsule 2-valved . . . . . *Saxifragaceæ.*
Petals 4. Stamens 4—8. Fruit, 4 nuts . *Haloragaceæ.*
Petals valvate in the bud.
Fruit a berry. Styles more than 2; leaves alternate . . . . . . *Araliaceæ.*
Fruit a drupe. Style 1; leaves opposite *Cornaceæ.*
Fruit a cremocarp . . . . . *Umbelliferæ.*
Petals twisted in the bud.
Sepals valvate . . . . . . *Onagraceæ.*

C. Corolla gamopetalous.

Flowers unisexual . . . . . . *Cucurbitaceæ.*

D. Corolla wanting.

Flowers monœcious. Stamens solitary. Ovary 4-celled . . . . *Haloragaceæ* (*Callitricheæ*).

Sub-Class III.—GAMOPETALÆ OR COROLLIFLORÆ.

The plants of this sub-class form a very well-marked group, differing from those already described in having the petals of the flower coherent together to form a corolla of one piece. The degree of union varies very widely: in some the petals are only attached together quite at their bases; in others the fusion is so complete that it is difficult to distinguish any indication of the constituent petals, the only indication of the actual structure being a number of minute teeth at the apex of the tubular corolla. In many of the Compositæ the tube formed by the complete fusion of the petals is slit down one side and flattened out into a strap-shaped structure, which is marked at its apex by a number of small notches. The calyx is usually gamosepalous; the stamens are, except in a very few families, attached to the tube of the corolla, generally at some little distance above its base. The ovary is commonly syncarpous, and in many cases is completely inferior. The sub-class shows us many degrees of fusion of the parts of the flower, and culminates in the Natural Order Compositæ, in which this fusion affects more or less every whorl, both of the perianth and the sporophylls.

Series 1.—*INFERÆ OR EPIGYNÆ.*

The plants of this series are distinguished by the possession of an inferior ovary.

Warming has suggested that the group includes plants which have followed two distinct lines of development, culminating in both cases in the collection of the flowers into capitula, the individual flowers showing various conditions of suppression. These two series take us respectively through the Rubiales to the Dipsaceæ, and through the Campanales to the Compositæ, the resemblances between the final orders of the two series being due to development upon parallel lines rather than to true affinity.

Cohort 1.—*Rubiales.*

The leaves of the plants of this group are arranged in whorls, sometimes of two, sometimes apparently of more. In the latter case six are frequently found. This is generally held to be due to the stipules of each leaf being of the same shape and size as the leaf itself, so that the whorl consists of two leaves and four stipules. This view is supported by the fact that branches arise in the axils of only two of the members of the whorl. When more than six apparent leaves are present it is held to be due to a division of some of the stipules. The flowers may be actinomorphic or zygomorphic; the sepals are minute and reduced to teeth, apparently springing from the top of the ovary. The corolla varies a good deal in the degree of its development. The pistil is composed of two to five carpels, and the ovary may contain one loculus or several. The seeds contain endosperm.

Order 1. CAPRIFOLIACEÆ.—The plants of this order are usually trees or shrubs, in some cases climbing. The leaves are opposite, sometimes connate, and in nearly all cases are exstipulate. Stipules occur, however, in a few isolated species, particularly of the genera *Sambucus*, *Lonicera*, and *Viburnum*. The leaves are simple in most cases, but compound ones are sometimes found. The flower may be actinomorphic or zygomorphic; the corolla is imbricate in æstivation. The carpels vary from two to five, but are generally three in number. The fruit is in most cases an inferior berry; in *Weigelia* a capsule, in *Linnæa* a nut.

The order is divided into the following tribes:—

1. *Sambuceæ.*—Corolla rotate, generally actinomorphic; ovules solitary in each loculus of the ovary. The inflorescence is umbellate, cymose.

FIG. 1172.

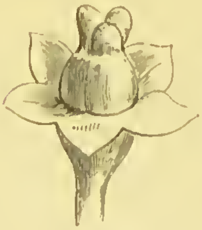


FIG. 1173.

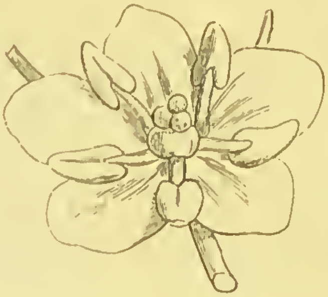


FIG. 1174.

Fig. 1172. Pistil of the common Elder (*Sambucus nigra*) surrounded by a superior 5-lobed calyx.——*Fig.* 1173. Entire flower of the same.——*Fig.* 1174. Vertical section of the seed.

2. *Loniccreæ.*—Corolla tubular, zygomorphic; several ovules occur in each loculus of the ovary.

3. *Linnæeæ.*—Corolla slightly bilabiate; stamens four, didynamous. Fruit a nut, enclosed in two large bracteoles.

The plants of this order are chiefly natives of the northern parts of Europe, Asia, and America; they are rare in the southern hemisphere. There are about 220 species. They have frequently showy flowers, usually fragrant. Among them may be mentioned the Honeysuckles, which are species of *Caprifolium* and *Lonicera*, the Guelder Roses (*Viburnum Opulus*), Laurustinus (*Viburnum Tinus*), and the Snowberry (*Symphoricarpus*).

Adoxa was formerly placed in the order, but it is now generally referred to *Saxifragaceæ*.

Order 2. RUBIACEÆ.—This order includes trees, shrubs, and herbs, the latter often twining or scrambling in habit. The leaves are simple and have interpetiolar stipules, which in many species are indistinguishable from the leaves, and are placed with the latter so as to form a whorl. The flowers are regular, and the corolla small and rotate. The æstivation of the corolla is often valvate. The pistil is bicarpellate, and the ovary may contain one or two cells. The seeds contain endosperm. The fruit is indehiscent, and in the British species separates into dry cocci; the ovary is crowned by a disc.

FIG. 1175. FIG. 1176. FIG. 1177. FIG. 1178.

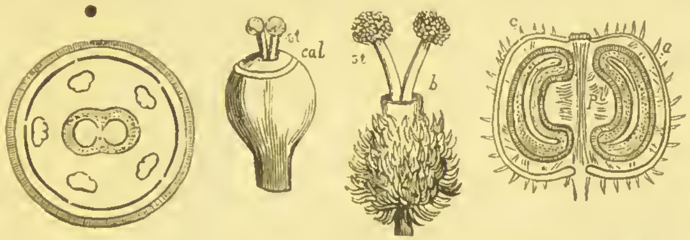


Fig. 1175. Diagram of the flower of the Madder (*Rubia tinctorum*).—*Fig.* 1176. Pistil of the Madder, with its ovary adherent to the calyx, *cal.* *st.* Styles and stigmas.——*Fig.* 1177. Pistil of the Goose-grass or Cleavers (*Galium Aparine*) adherent to the calyx, *b*, by its ovary. *st.* Styles.——*Fig.* 1178. Vertical section of the fruit and seeds of the same. *a.* Albumen. *c.* Embryo. *pl.* Placenta.

The chief families of this order are the following:

1. *Coffeeæ.*—The fruit is succulent and contains two stones. *Coffea arabica* is the Coffee tree; the coffee beans are its seeds. They contain a hard horny endosperm, in which is embedded a embryo.

2. *Cinchoneæ.*—The fruit is a capsule and contains a number of seeds which are winged. *Cinchona* is the source of quinine.

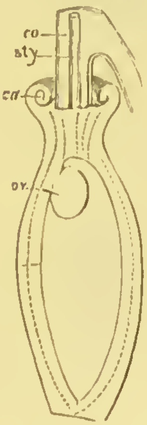
3. *Stellatæ.*—This section of the order is characterised by the whorls of leaves, the true nature of which has already been mentioned. The whorls are not decussate. The calyx is rudimentary; a solitary ovule is present in each loculus of the ovary. The fruit is a schizocarp, and in some species is furnished with a number of hook-like outgrowths which aid in the dispersion of the seeds.

The properties of the plants of the Rubiaceæ are very important. Many possess tonic, febrifugal, astringent, emetic, or purgative properties; some are diuretic and emmenagogue; a few are valuable dyeing and tanning agents; and others have edible fruits and seeds. Among the products of the order are coffee, quinine, and ipecacuanha.

Cohort 2.—*Asterales.*

This group includes four Natural Orders, which show a tendency to reduction in the parts and the dimensions of the flowers, together with an aggregation of them into dense masses or collections. In three of these orders the inflorescence is a capitulum, or a collection of capitula arranged in cymose or racemose fashions. The flowers are small and generally zygomorphic; this symmetry is due to suppression in the gynœcium, or to irregularity in the corolla. The calyx is often so closely attached to the ovary that it appears to be absent; it is never conspicuous. The ovary has only one cell when mature, though there may be more when the flower is young. The ovule is solitary.

FIG. 1179.



1179. Vertical section of the ovary, &c., of the Red Valerian (*Centranthus ruber*). *ca.* Calyx. *co.* Corolla. *sty.* Style. *ov.* Ovule.

Order 1. VALERIANACEÆ.—This order includes herbs and undershrubs which bear opposite exstipulate leaves. The inflorescence is peculiar among the members of the cohort in being in close-set cymes, which are sometimes dichasial, sometimes scorpioid. The capitulum does not occur. The calyx is in most cases a mere rim round the apex of the ovary; as the fruit advances in age it sometimes becomes a pappus. The corolla is often zygomorphic, owing to the formation of a spur. The order exhibits suppression in the andrœcium; in *Valeriana* only three of the typical five stamens are seen; in *Fedia* two; and in *Centranthus* only one. There are three carpels, and in the young condition the ovary exhibits three cells, but only one contains an ovule, and as the fruit ripens the other two become almost entirely absorbed. The solitary ovule is pendulous, and develops into a seed without endosperm.

The Valerianaceæ are chiefly natives of the temperate parts of Europe, Asia, and America; they are rare in Africa. There are about 275 species. The rhizomes of some of them contain a strong-scented volatile oil, which renders them stimulant, antispasmodic, and tonic.

Order 2. Dipsaceæ.—The plants of this order are all herbaceous, and bear opposite exstipulate leaves. The inflorescence is a capitulum or group of capitula, each having an involucre of green phyllaries below it. The flowers of this order differ from those of any other members of the cohort by having a small bracteate involucel or epicalyx situated below it. The bracteoles are fused together, so that the epicalyx is cup-like. The calyx is more prominent than in the last order, and is often membranous or pappose; the corolla is zygomorphic, often almost bilabiate; in some cases two of the petals are almost completely fused together, so that the number appears to be only four. The stamens are four and are free; the suppression in this case affects the posterior stamen. The ovary is bicarpellary, 1-celled, and contains a solitary pendulous ovule. The seed has endosperm, and the radicle is superior.

Fig. 1180.

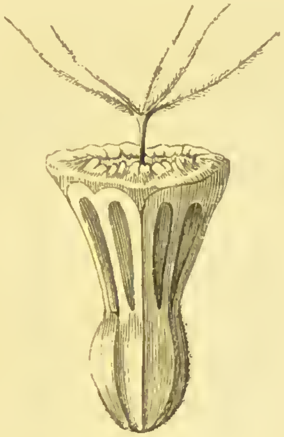


Fig. 1181.

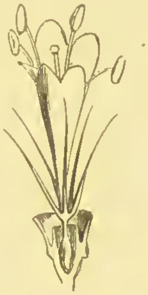


Fig. 1180. Fruit of *Scabiosa purpurea* (*Dipsaceæ*), surmounted by the pappose calyx.——*Fig.* 1181. One of the central florets of the capitulum of *Scabiosa purpurea*, with the ovary, &c., cut vertically.

A curious feature in the Dipsaceæ is that the order of expansion of the flowers is neither centrifugal nor centripetal. The first to unfold are in most cases those which occupy a zone about in the centre of the capitulum. Some authors trace this to the probable development of the capitulum from the coalescence of a number of dichasia, such as are found in the *Valerianaceæ*.

The Dipsaceæ are chiefly natives of the south of Europe and of North and South Africa. A few species only are British. There are about 150 to 170 species.

Order 3. Calyceraceæ.—This is a small order of American plants which are intermediate between *Dipsaceæ* and *Compositæ*. They differ from the former in having alternate leaves, no involucels, and stamens united by their filaments and partly by their anthers; from the latter, in this union being but slight, and in their having pendulous seeds containing endosperm.

Order 4. Compositæ.—The plants of this order are herbs or shrubs with alternate or opposite exstipulate leaves. The inflorescence is a capitulum, which generally consists of a very large number of flowers, seated on a convex or flattened receptacle. The number varies very greatly, in one case only a single one being present. The flowers show a great deal of suppression, which affects both the perianth and the sporophylls. The calyx is seldom recognisable as such, being represented by a pappus, or altogether absent. The suppression in the sporophylls affects the andrœcium more frequently than the pistil, but in some cases both whorls are absent; in the latter case the corolla is, as a rule, developed more than in the perfect flowers. The arrangement of the flowers in the capitulum also varies: in some cases they are all perfect; in others sterile flowers are placed round the circumference, while perfect ones occupy the centre. The corolla is composed of five petals, which are typically arranged to form a tube with five small teeth at its apex (*fig.* 1182). In some cases this tubular corolla is slit open down one side almost to the base, and flattened out (*fig.* 1183). Such a corolla is termed *ligulate*. In many capitula the flowers round the circumference have ligulate corollas, sometimes containing no stamens and sometimes no sporophylls at all. These flowers are often called 'florets of the ray,' in contradistinction to those of the centre, which have tubular corollas and are known as 'florets of the disc.' In some capitula this distinction is not seen; the florets are all ligulate or all tubular. In other cases the corollas are bilabiate. The stamens are always five, and their anthers are united together, forming a tube through which the style passes. This attachment of the stamens is known as *syngenesious*, to distinguish it from the *monadelphous* condition, in which the cohesion affects the filaments only. The pistil is bicarpellary; the ovary 1-celled, with a single basal erect ovule, which springs from the axis and not the carpels. It affords an instance of the occurrence of axial sporangia in the Phanerogams. The seed has no endosperm.

FIG. 1182.

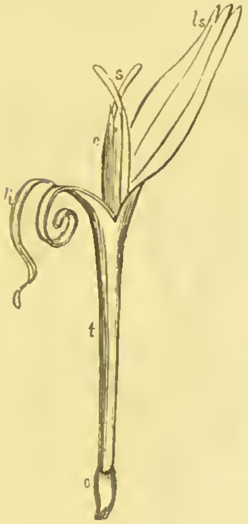


FIG. 1183.

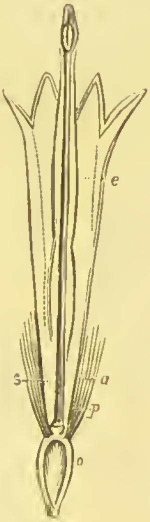


FIG. 1184.

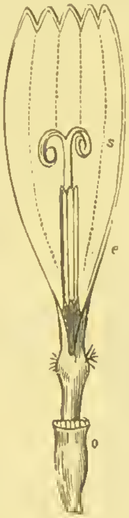


FIG. 1185.

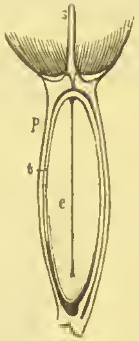


Fig. 1182. Labiate floret of *Chælanthera linearis*. *o*. Ovary with adherent calyx. *t*. Tube of the corolla. *ls*. Upper lip of the corolla. *li*. Lower lip. *e*. Tube formed by the united anthers. *s*. Stigmas.——*Fig.* 1183. Vertical section of the floret of *Aster rubricaulis*. *o*. Ovary containing one erect ovule. *a*. Pappus calyx. *p*. Corolla. *s*. Style. *e*. Tube formed by the united anthers.——*Fig.* 1184. Floret of the Chicory (*Cichorium Intybus*). *o*. Ovary with adherent calyx. *e*. Tube formed by the united anthers. *s*. Stigmas.——*Fig.* 1185. Vertical section of the ripe fruit of the Groundsel (*Senecio*), surmounted by a portion of the style, *s*; and the pappus calyx. *p*. Pericarp. *t*. Testa. *e*. Seed. (After Jussieu).

The capitulum is always surrounded by an involucre of phyllaries, sometimes arranged in several series. The involucel or epicalyx of the Dipsaceæ is not represented. Some species have each floret or flower situated in the axil of a scarious bract springing from the thalamus. These are known as the *paleæ of the receptacle*.

The order has been variously divided by different authors. By Linnæus, the plants of his class Syngenesia, division Polygamia (which corresponded to the Natural Order Compositæ), were arranged in five orders, under the names of *Polygamia æqualis*, *P. superflua*, *P. frustranea*, *P. necessaria*, and *P. segregata*. Jussieu separated the Compositæ into three sub-orders as follows:—1. *Corymbiferæ*, the plants of which have either all tubular and perfect florets; or radiant, those of the disc being tubular and perfect, and those of the ray generally ligulate and pistilliferous. 2. *Cynarocephalæ*, the florets of which are all tubular and perfect; or those of the disc perfect, and those of the ray neuter. And 3. *Cichoraceæ*, having all the florets ligulate and perfect. A fourth sub-order was afterwards added, called *Labiatifloræ*, which includes those plants the florets of which were bilabiate, and which were unknown to Jussieu.

FIG. 1186.

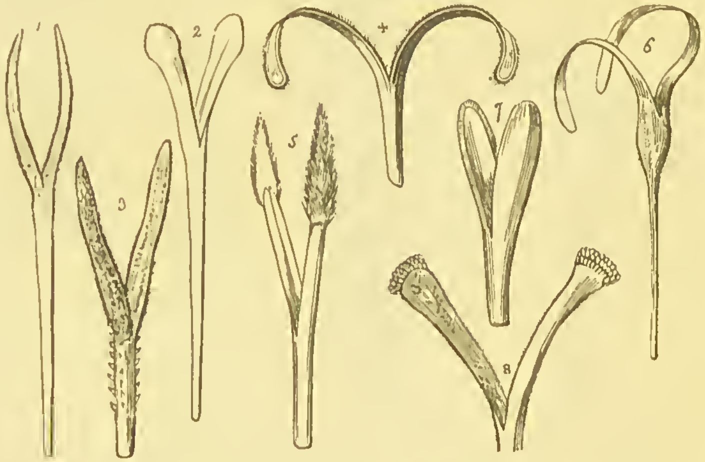


Fig. 1186. Styles and stigmas of composite flowers. 1. *Albertinia erythropappa* (Helianthoideæ). 2. *Anisochæta mikanioides* (Eupatorieæ). 3. *Blumea senecioides* (Asteroideæ). 4. *Menderia bicolor* (Senecioideæ). 5. *Lipochæta umbellata* (Senecioideæ). 6. *Aplotaxis nepalensis* (Cynareæ). 7. *Leucomeris spectabilis* (Mutisieæ). 8. *Leuceria tenuis* (Nassauvieæ).

The arrangement most frequently adopted at the present day is as follows:—

Sub-order 1. TUBULIFLORÆ.—Florets all tubular and perfect; or those of the centre (*disc*) are tubular, and alone perfect, while those of the circumference (*ray*) are tubular or ligulate, and pistillate or neuter; juice watery. This sub-order includes the Corymbiferæ and Cynarocephalæ of Jussieu. It has been divided into nine tribes as follows:—

Tribe 1. *Eupatorieæ.*—Opposite leaves; florets tubular; style cylindrical, with narrow branches; papillose surface near the end.

Tribe 2. *Asteroideæ.*—Style cylindrical; its arms linear, flat on the outside, equally and finely downy on the inside; papillose surface extending to the hairs. Leaves alternate.

Tribe 3. *Senecionideæ.*—Florets of the ray generally present, ligulate, pistillate; style cylindrical, its branches linear and tufted. Leaves alternate.

Tribe 4. *Anthemideæ.*—Ray florets sometimes tubular, pistillate; pappus minute, sometimes absent. Style as in Tribe 4.

Tribe 5. *Helianthoideæ.*—Leaves opposite. Ray florets pistillate or neuter, ligulate, sometimes absent. Style cylindrical, branches hairy on the inside. Paleæ of receptacle generally present.

Tribe 6. *Helenioideæ.*—Like Tribe 5, but no paleæ of the receptacle.

Tribe 7. *Inuloideæ.*—Leaves alternate; anthers with two bristles a their base. Ray florets sometimes absent.

Tribe 8. *Calenduleæ.*—The ray florets pistillate, those of the disc staminate. Pappus absent, no paleæ of the receptacle. Fruits large, warty.

These tribes correspond to the sub-order Corymbiferæ of Jussieu; the next forms the Cynarocephalæ of the same author.

Tribe 9. *Cynareæ.*—Style thickened above, and often with a bunch or ringe of hairs at the enlarged portion; its branches united or free.

Sub-order 2. LABIATIFLORÆ.—Florets with bilabiate corollas, perfect or unisexual. Juice watery. Of this sub-order we have two tribes:—

Tribe 10. *Mutisieæ.*—Style cylindrical or somewhat swollen; its arms usually blunt or truncate, very convex on the outside, and either covered at the upper part by a fine uniform hairiness, or absolutely free from hairs.

Tribe 11. *Nassauvieæ.*—Style never swollen; its arms long, linear, truncate, and fringed only at the point.

Sub-order 3. LIGULIFLORÆ.—Florets all ligulate and perfect. Juice milky. This corresponds to the Cichoraceæ of Jussieu.

Tribe 12. *Cichoreæ.*—Style cylindrical at the upper part; its arms somewhat obtuse, and equally pubescent.

The flowers owe their conspicuousness to being crowded together into capitula. They are generally cross-pollinated, the peculiar arrangement of the style and stamens rendering self-pollination difficult. The tube of the corolla is in most cases charged to a greater or less extent with honey, attracting particularly butterflies and bees. The stamens are protandrous, and discharge their pollen introrsely, filling up the little box which is made by their syngenesious attachment. The style at this period has not reached its full elongation, and remains in the centre of the box with its stigmatic surfaces closely pressed together, preventing any pollen from reaching them. A little later the style grows in length, and sweeps the pollen which surrounds its closed branches out of the top of the pollen box. The lobes then separate slowly and expose the stigma. The pollen of the flower has been mainly swept away before this expansion; what little is left adhering to the style is on the exterior surface of its branches, where there are no stigmatic papillæ. The pollen is thus shed on to the top of the inflorescence, and is distributed by the visiting insects, mainly reaching the stigmas of other flowers and being partly removed to other capitula by the intruders. Self-pollination is, of course, not impossible under this arrangement, but the dichogamy renders it unlikely in most cases. It is found, however, in *Senecio*. In some tribes wind-pollination occurs.

The order Compositæ is the largest known, including about 12,000 species. It is universally distributed, but its sub-orders are not equally represented everywhere. The *Tubulifloræ* are most abundant in hot and the *Liguliforæ* in cold climates. The *Labiatæfloræ* are almost entirely confined to the extra-tropical regions of South America. In the northern parts of the world the plants of this order are universally herbaceous; in some parts of the southern hemisphere they are shrubby, and a few are arborescent.

The properties of the plants of the order vary greatly. A bitter principle, which has tonic properties, is almost universal in them. Some are laxative and anthelmintic. Many contain a volatile oil, which communicates aromatic, carminative, and diaphoretic properties. Others are acrid stimulants; and the *Liguliforæ* commonly abound in a bitter milky juice, which is sometimes narcotic.

Cohort 3.—*Campanales*.

The plants of this group have their stamens attached to the top of the ovary, and not, like most of the Gamopetalæ, to the corolla. They are sometimes syngenesious, sometimes free. The flowers are pentamerous, sometimes actinomorphic, sometimes zygomorphic. Suppression however occurs, particularly in the gynœcium, which is generally tricarpellary. The ovules are numerous in each of the loculi, and are arranged on an axile placenta; and the fruit is a capsule, and the seeds contain endosperm. The plants are usually herbs, rarely shrubs; they have generally a milky latex.

Order 1. STYLIDIACEÆ.—A small Australian order, embracing about 100 species. The flowers are zygomorphic and have only two stamens, which are united to the style.

Order 2. Goodeniaceæ.—A small order, also chiefly Australian, embracing about 200 species.

Order 3. Campanulaceæ.—The plants of this order are herbs or shrubs, and bear alternate exstipulate leaves; they have usually a milky juice. The inflorescence is generally racemose, but the axis terminates in a flower. It is a capitulum in *Jasione*. The flowers are actinomorphic or zygomorphic, the corolla in the former case being campanulate; sometimes the zygomorphy is due to suppression in the gynœcium. The stamens do not adhere to the corolla, but are epigynous; the filaments are broad, almost circinate at their bases; and the anthers are in many cases more or less coherent. The flowers are protandrous; and the stamens wither after discharging their pollen. The ovary is in some cases only half inferior, and is generally trilocular, containing numerous ovules in each cell, arranged on an axile placenta. The style is sturdy and covered with hairs, on which the pollen is collected when the stamens have dehisced. The fruit is a capsule.

Fig. 1187.

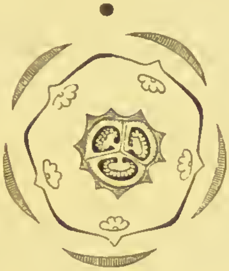


Fig. 1188.

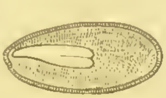


Fig. 1189.

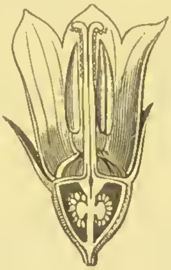


Fig. 1187. Diagram of the flower of Rampions (*Campanula Rapunculus*).——*Fig.* 1188. Vertical section of the seed.——*Fig.* 1189. Vertical section of the flower.

Fig. 1191.

Fig. 1190.

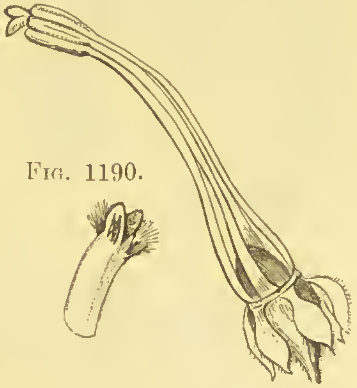


Fig. 1190. Stigma of *Lobelia syphilitica*.——*Fig.* 1191. The sporophylls of the above, with the calyx.

The order comprises the following two sections:—

1. *Campanuleæ*.—Flowers actinomorphic; anthers free. Inflorescence with a terminal flower.
2. *Lobelieæ*.—Flowers zygomorphic; corolla bilabiate; anthers

syngenesious; stigma with hairs at its base (*fig.* 1190); no termina flower to the inflorescence.

The plants of this order are natives chiefly of the temperate part of the northern hemisphere; many are found also in the southern hemisphere, especially at the Cape of Good Hope. A few species are tropical. About 900 to 1,000 species are known.

Series 2.—*Heteromeæ or Superæ.*

In this group the ovary is superior, except in the order *Vacciniaceæ*; the stamens are epipetalous, but sometimes attached so near the base of the petals as to appear almost or quite free and hypogynous. Carpels more than two.

Cohort 1.—*Ericales.*

The stamens are hypogynous except in *Vacciniaceæ*; they may be in a single whorl alternate with the corolla lobes, or may be obdiplostemonous. The ovary is inferior in *Vacciniaceæ*, superior in the rest of the orders of the cohort; the ovary has usually more than two cells, and the placentation is axile. The seeds are endospermous.

Fig. 1192.

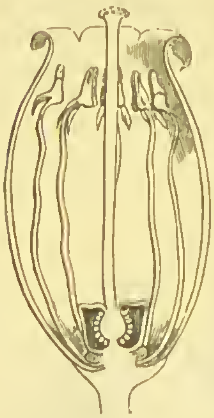


Fig. 1193.

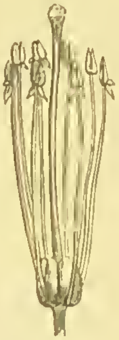


Fig. 1192. Vertical section of the flower of a species of Heath (*Erica*). ——*Fig.* 1193. Sporophylls of the same. The stamens are seen to be hypogynous.

Order 1. Vacciniaceæ.—This is a small order consisting of shrubs and small trees. The flowers are characterised by their inferior ovary, gamopetalous corolla, and baccate fruit; the stamens are epigynous; the anthers bear appendages and dehisce by pores.

Order 2. Ericaceæ.—The plants of this order are shrubs of a very wiry habit, which bear small, generally folded leaves. The flowers are hypogynous; the petals are coherent, but in some cases only very slightly at their bases; the corolla is generally persistent and marcescent. The stamens are in two whorls; the anthers are appendiculate, and dehisce by pores as in the last order. The fruit is commonly a capsule, but sometimes it is succulent. The ovary has a disc at its base.

The order is subdivided as follows :—

Tribe 1. *Arbuteæ.*—Corolla deciduous. Fruit baccate.
Tribe 2. *Andromedeæ.*—Buds usually clothed with scales. Corolla deciduous. Fruit capsular, loculicidal.
Tribe 3. *Ericeæ.*—Buds naked. Corolla persistent. Fruit capsular, usually loculicidal, or rarely septicidal.
Tribe 4. *Rhodoreæ.*—Buds scaly, cone-like. Corolla deciduous. Fruit capsular, septicidal.
Tribe 5. *Pyroleæ.*—Herbs or somewhat shrubby plants. Corolla polypetalous, or the petals united at the base, deciduous. Fruit capsular, loculicidal.

The plants of the order are very abundant at the Cape of Good Hope, and are also more or less generally distributed in Europe, North and South America, and Asia. There are more than 900 species.

They are chiefly remarkable for astringent properties; some are tonic and diuretic, and others are narcotic, or even poisonous. This is especially the case with *Kalmia latifolia*, *Rhododendron chrysanthum*, *Andromeda floribunda*, and *Azalea pontica*. The fruits of many are edible.

Order 3. MONOTROPACEÆ.—A small order of saprophytes with scale-like leaves containing no chlorophyll. The stamens are hypogynous, obdiplostemonous; the fruit is a loculicidal capsule with parietal placentation.

Order 4. EPACRIDACEÆ.—A small order of Australian Heaths, differing from *Ericaceæ* chiefly by the antipetalous stamens being suppressed. The anthers dehisce longitudinally instead of by pores.

Order 5. DIAPENSIACEÆ.—A small order of Arctic plants in which the antipetalous stamens are either absent or represented by staminodes. By some writers this order is placed near the *Polemoniaceæ* and *Hydrophyllaceæ*. The ovary is tricarpellary.

Order 6. LENNOACEÆ.—A small order of root parasites whose leaves contain no chlorophyll.

Cohort 2.—*Primulales.*

The plants of this group are characterised by the peculiarities that the stamens are equal in number to the petals and are opposite to them; that the ovary is unilocular and bears a free-central placenta, on which one or many ovules may be found.

These peculiarities have given rise to considerable discussion. The single whorl of antipetalous stamens is usually explained now on the hypothesis that the flower has been diplostemonous, and the outer or antisepalous whorl has been suppressed. There are many facts which support this view. In certain genera of the Primluaceæ, *Samolus*, *Lysimachia*, and *Soldanella*, traces of such a whorl can be recognised in small staminodal structures which occupy the positions of its missing stamens. In the *Myrsinaceæ* the occurrence of these bodies is still more general, and they are in many cases petaloid. The occurrence of this staminodal development is found also in the next cohort, the *Ebenales*.

Another view has been the subject of discussion. There are apetalous genera in the cohort, and it has been said that this is the normal condition. The early development of the flower appears to show a single protuberance arising for each stamen and the petal behind it, and the latter has consequently been held to be a ligular outgrowth of the staminal leaf. Frank has combated this view, alleging that in the youngest condition of the flower this apparently single protuberance was really double, and that the two fused during their early growth, separating again later on.

The generally accepted view, as stated above, appears to be based upon satisfactory evidence.

The free-central placenta has been held by many botanists to be a case of axial sporangia, such as are found in certain of the Cryptogams and in the *Compositæ*, but much more pronounced than in the latter group.

Others have attempted with much ingenuity to reconcile the structure with the foliar type of placentation. On their hypothesis the flower has five carpels with axile placentation, the ovules being consequently on their ventral faces. The lateral portions of the carpels are considered to be suppressed so that the dorsal portions form the wall of the ovary, while the ventral parts are united into a free-central placenta. This view is rather difficult to hold in the case of the *Plumbaginaceæ*, where the placenta is quite basal and bears a single pendulous ovule upon a long twisted funicle, the latter rising from the bottom of the ovary. To explain this we must assume the complete development of the dorsal portions of the carpels and the equally complete abortion of their ventral parts, the latter being reduced to the floor of the ovary. The view that the ovules or megasporangia are borne upon the axis of the flower which protrudes into the cavity of the ovary formed by lateral fusion of the carpels has much to recommend it, especially since the demonstration that sporangia in the lower groups of plants may arise upon either stem or leaves.

Order 1. PLUMBAGINACEÆ.—The plants of this order are herbs or undershrubs, chiefly found upon sandy sea-shores or deserts. Their leaves are borne spirally upon the stem, and they are often small and wiry, or fleshy. Sometimes rosettes of radical leaves occur. The calyx is membranous ; the cohesion of the petals is sometimes very slight, the flower appearing almost or quite polypetalous; the five antipetalous stamens are attached to the petals at their bases; the pistil is composed of five carpels; the ovary is 1-celled; the styles are free and spreading. There is a single basally placed ovule, which is pendulous on a long stalk.

Fig. 1194.

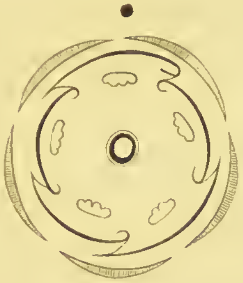


Fig. 1195.

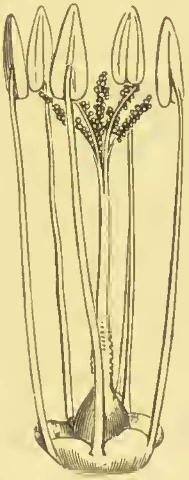


Fig. 1194. Diagram of the flower of a species of *Plumbago*.——*Fig.* 1195. Sporophylls of the same.

Fig. 1196.

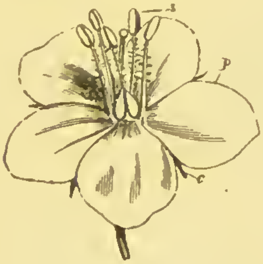


Fig. 1197.

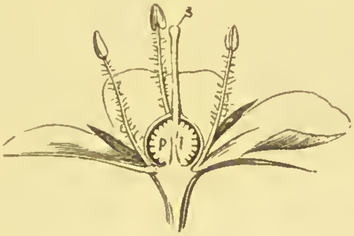


Fig. 1198.

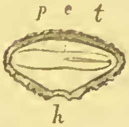


Fig. 1196. Flower of the Pimpernel (*Anagallis arvensis*). *c.* Calyx. *p.* Petals. *s.* Stamens.——*Fig.* 1197. Vertical section of the flower of the same. *pl.* Free-central placenta. *s.* Style and capitate stigma.——*Fig.* 1198. Vertical section of the seed of *Primula elatior*. *t.* Integuments. *p.* Albumen. *e.* Embryo. *h.* Hilum.

The inflorescence is generally a number of cymes, but in *Armeria* it is a capitulum.

Order 2. Primulaceæ.—This is the most important order of the cohort. The plants included in it are all herbaceous, with simple exstipulate cauline or radical leaves. These are much divided in the aquatic genus *Hottonia*. The flowers are, as a rule, pentamerous and regular. They have the structure of the cohort, and are specially marked by the large placenta covered with numerous seeds, and by a complete fusion of the styles, which form a rod-like body crowned by the stigma. The fruit is a capsule.

There are several genera which exhibit peculiarities. The flowers of some species of *Primula* are dimorphic, one form having the stamens carried at the throat of the corolla, while the style reaches about halfway up its tube, the other having these positions reversed. *Samolus* has its ovary half inferior. In *Trientalis* the flower is heptamerous, in *Centunculus* usually tetramerous; *Glaux* has no corolla; *Samolus*, certain species of *Lysimachia*, and *Soldanella* have a whorl of scaly staminodes opposite to the sepals. *Cyclamen* has only one cotyledon. *Anagallis* has opposite leaves, and its fruit is a pyxis. *Hottonia* lives in ponds and slow streams, and has much-divided leaves.

Order 3. Myrsinaceæ.—This is a small order of arborescent evergreen plants which are natives of the southern hemisphere. They differ from the last order chiefly in their habit and in bearing baccate fruits. They have a whorl of antisepalous staminodes, which are sometimes petaloid.

Cohort 3.—*Ebenales*.

The plants of this group have regular flowers which are typically diplostemonous, though the outer whorl of stamens is sometimes suppressed. The ovary is multilocular, and the placentation is axile. The fruits are fleshy, and the seeds large; the latter contain endosperm.

Order 1. Sapotaceæ.—An order of tropical trees which contain abundant latex. Some of them are the source of *gutta-percha*.

Order 2. Ebenaceæ.—The plants of this order are also tropical trees. They have no milky latex, and their flowers are in many cases diclinous.

Order 3. Styraceæ.—In this order the cohesion of the petals is very slight, and the ovary is more or less inferior. The stamens are often two or three times the number of the petals, and in some cases are monadelphous.

Series 3.—*BICARPELLATÆ.*

In this group the ovary is superior, and consists usually of two carpels. The stamens are epipetalous.

Cohort 1.—*Gentianales.*

The plants of this cohort usually bear opposite decussate leaves without stipules; the corolla is regular; the stamens generally epipetalous, equal to and alternate with the lobes of the corolla, rarely fewer. The pistil consists of two carpels.

Order 1. OLEACEÆ.—This order is composed of trees and shrubs with opposite exstipulate leaves. The flowers are usually perfect, but in some cases diclinous. The calyx and corolla are sometimes absent, but when present are tetramerous. There may be four or eight members of each whorl. The stamens are two, or rarely four. The ovary is superior, 2-celled, with two usually pendulous ovules in each loculus. The seeds have generally copious endosperm.

The fruit varies in the different tribes, which are the following:—

Tribe 1. *Oleineæ.*—Fruit a berry or drupe. The former is found in the Privet (*Ligustrum*), and the latter in the Olive (*Olea*).

Tribe 2. *Fraxineæ.*—Fruit a samara. *Fraxinus*, the Ash, has no perianth.

FIG. 1199.

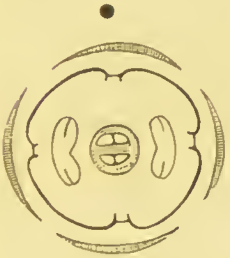


FIG. 1200.

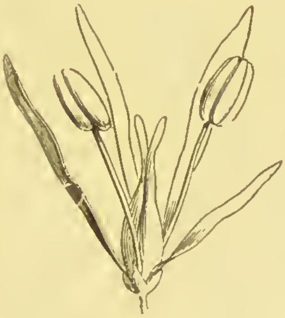


FIG. 1201.

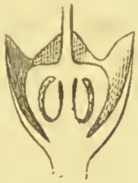


Fig. 1199. Diagram of the flower of the Lilac (*Syringa vulgaris*).——*Fig.* 1200. Flower of the Manna Ash (*Fraxinus Ornus*), with 4-cleft calyx; corolla with four distinct petals; two stamens; and two carpels.——*Fig.* 1201. Vertical section of the calyx and pistil of the Privet (*Ligustrum vulgare*).

Tribe 3. *Syringeæ.*—Fruit a capsule, dehiscing loculicidally.

Tribe 4. *Jasmineæ.*—Fruit a capsule or berry. This tribe is by some botanists considered a distinct Natural Order. It is marked by the imbricate æstivation of the corolla, the erect ovules, and the small quantity of endosperm in the seed.

Order 2. SALVADORACEÆ.—A small order of arborescent plants found in India, Syria, and North Africa. There are only eight or nine species.

Order 3. APOCYNACEÆ.—The plants of this order are mostly trees and shrubs, sometimes of climbing habit; there are some herbaceous species. They generally contain a milky acrid latex. The leaves are opposite, exstipulate, simple, and entire. The calyx is persistent; the corolla exhibits contorted æstivation. The stamens are free; there are two carpels, which are in most cases united only by their styles, and usually become two follicles, or two drupes, in fruit. The coherent styles are crowned by a curious dumb-bell-shaped stigma. In some genera the carpels are coherent completely to form a capsule, which may be 1-celled with parietal, or 2-celled with axile placentation. In other genera the fruit is a berry. The seeds are generally endospermous, and bear a tuft of hairs.

FIG. 1202.

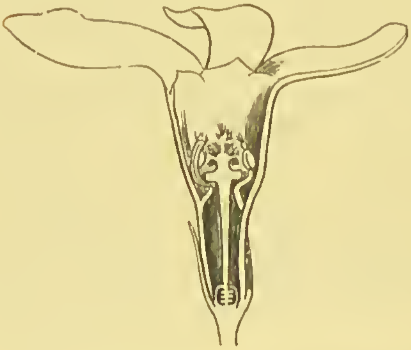


FIG. 1203.

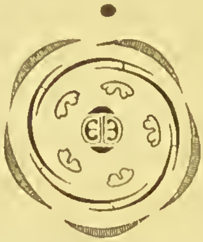


Fig. 1202. Vertical section of the flower of Periwinkle (*Vinca*).
Fig. 1203. Diagram of the flower of the same.

Order 4. ASCLEPIADACEÆ.—This is a Natural Order closely allied to the last, but exhibiting striking peculiarities in the arrangement of its sporophylls. The plants are shrubs or herbs with a milky latex, which in many cases is poisonous. The leaves are opposite and entire, exstipulate. The union of the styles observed in the last order is found also in this, but the stigma forms a large pentangular body at their apices (*fig.* 1204). The stamens surround this angular body and are closely pressed against it. The anther lobes are two; and the pollen grains are agglutinated together to form a pollinium in each, much as is the case in the *Orchidaceæ*. At each angle of the stigmatic head is a gland, and below this the groove formed by the approximation of the anthers. This groove secretes a sticky disc called a corpusculum, and from this the sticky secretion extends on each side of the groove to the pollinium contiguous to it, so that the left-hand pollinium of one anther is united to the right-hand one of the anther next it, forming a curious forked body (*fig.* 1204, *b*). The receptive surface of the stigma is in the groove below the corpusculum. The stamens have a curious appendage, the *cucullus* (*figs.* 1206, 1207), which functions as a nectary. The fruit consists of two follicles; the seeds are numerous and bear a tuft of hairs; there is but little endosperm.

Fig. 1204.

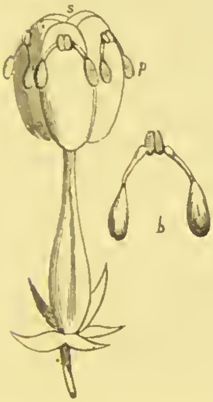


Fig. 1205.

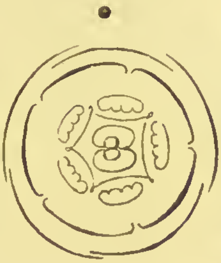


Fig. 1206.

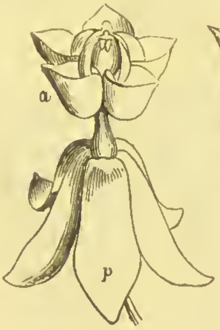


Fig. 1207.

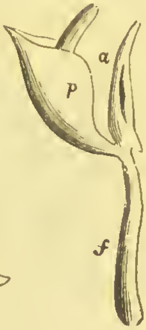


Fig. 1204. Pistil of a species of *Asclepias*, with pollinia, *p*, hanging freely. *b*. Pollen-masses as detached from contiguous anthers.——*Fig.* 1205. Diagram of the flower of *Asclepias nivea*.——*Fig.* 1206. Flower of a species of *Asclepias*, with the stamens united and forming a tube round the pistil. *p*. Corolla. *a*. Appendages of the stamens.——*Fig.* 1207. One of the stamens of the same removed. *f*. Filament. *a*. Anther. *p*. Hornlike appendage of the filament.

The plants are pollinated by bees, which, crawling over the flowers, catch their feet in the grooves at the angles of stigmas, and consequently withdraw the corpuscula with the two pollinia attached. These are subsequently deposited in other grooves during the insects' wanderings, and either left there or broken, and the pollen rubbed on the stigmatic surface in the groove.

Order 5. Loganiaceæ.—A small tropical order of arborescent plants, many of which have a climbing habit. They are almost universally poisonous, acting on the nervous system and producing frightful convulsions. Several have been used in medicine in torpid or paralytic conditions of the muscular system, and for their valuable tonic, anthelmintic, and other properties.

Order 6. GENTIANACEÆ.—The plants of this order are in most cases herbaceous, and contain no latex. The leaves are, except in *Menyantheæ*, opposite, entire, exstipulate, and sometimes slightly connate at their bases (*Chlora*). The inflorescence is typically cymose, dichasia often occurring (*fig.* 1208); in some species the flowers are solitary. The calyx is usually polysepalous; the corolla tubular and marcescent. The ovary is 1-celled, or partially 2-celled from the ingrowth of two well-marked parietal placentas. The fruit is a septicidal 2-valved capsule; the seeds are numerous, anatropous in form, and contain endosperm.

FIG. 1208.

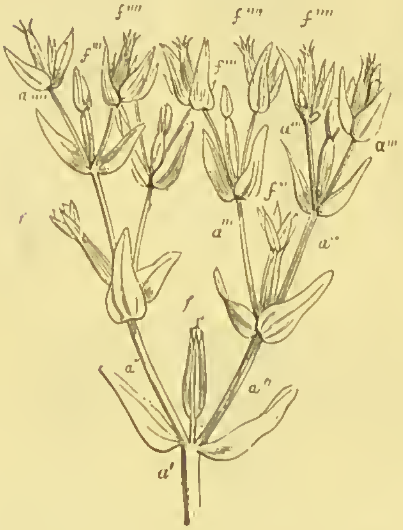


Fig. 1208. Dichasial cyme or Dichasium of the Centaury (*Erythræa Centaurium*). a', a'', a''', a''''. Floral axes. f', f'', f''', f''''. Flowers terminating those axes respectively. The flowers will be observed to be most developed in proportion to their age; thus f' is in the state of fruit: f'', f'', expanded; f''', f''', f''', and the others still in bud.

There are two divisions of the order, which differ greatly in habit.

1. *Gentianeæ.*—These plants have the characters given for those of the order; their corolla is contorted in æstivation.

2. *Menyantheæ.*—These are aquatic plants, with alternate leaves and a valvate æstivation to the corolla. *Menyanthes*, the Buck-bean, has erect ternate leaves, while those of *Limnanthemum* (*Villarsia*) float upon the surface after the manner of the Water-lilies. In *Menyanthes* the carpels are placed obliquely.

The Gentianaceæ are cosmopolitan in their distribution, and many of them are Alpine. There are nearly 600 species. Most of them contain a bitter principle, being tonic, stomachic, and febrifugal.

Cohort 2.—*Polemoniales.*

The plants of this group have generally alternate leaves, usually simple and entire, though lobed and compound forms occur; they are always exstipulate. The corolla is regular or nearly so; the stamens equal in number to and alternate with the corolla lobes. In a few cases there are more than two carpels.

Order 1. POLEMONIACEÆ.—This is a small order, including not more than 150 species, which are most abundant in North America. They have a tricarpellary pistil, forming a 3-celled ovary with axile placentation, and bearing a trifid style.

Order 2. HYDROPHYLLACEÆ.—A very small order of principally North American plants, which resemble in habit the *Boraginaceæ*. They differ from the latter in having an ovary which is usually 1-celled with two parietal placentæ.

Order 3. BORAGINACEÆ.—The plants of this order have a very characteristic vegetative habit. They are herbs or rarely trees, with usually rounded, rough, hairy stems, bearing alternate leaves which are also rough. The hairs are stiff and harsh, sometimes almost stinging. In a few species this hispid character is wanting. The inflorescence consists of a number of helicoid cymes, usually arising in pairs, often with a single flower at the bifurcation. The flowers are regular except in one or two species, where a slight zygomorphy occurs. The corolla is rotate ; and the petals often bear ligular outgrowths or scales at the junction of the claw and limb. The stamens alternate with the corolla lobes. The two carpels form a 4-lobed ovary in consequence of the development of a false septum, which grows inwards and downwards from the midrib of each carpel and causes a constriction into two, which then develop separately and curve inwards and downwards, causing the style to arise from the apparent base of the ovary between the four lobes. The receptacle on which the carpels rest frequently forms a conspicuous conical disc (*fig.* 1209). The position of the style is termed *gynobasic*. Each lobe of the ovary is 1-celled and contains a pendulous anatropous ovule. The fruit is a schizocarp, splitting into four nutlets. The

FIG. 1209.

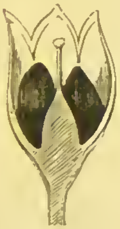


FIG. 1210.

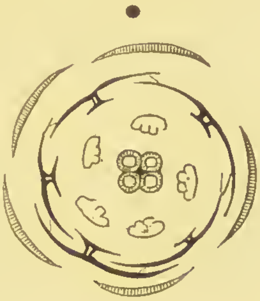


Fig. 1209. Vertical section of the fruit of a species of *Myosotis*. Two lobes are seen, and two have been removed.——*Fig.* 1210. Diagram of the flower of the Comfrey (*Symphytum officinale*).

seeds contain no endosperm except in a few cases; the radicle is superior.

The order may be conveniently divided as follows :—

Sub-order 1. *Ehretieæ.*—In this group, which some botanists prefer to consider a separate order, the style is terminal and the ovary does not become 4-lobed. In some genera the fruit is a drupe.

Sub-order 2. *Cordieæ.*—This group includes only arborescent forms, with drupaceous fruits.

Sub-order 3. *Borageæ.*—In this group the style is gynobasic, and the fruit a schizocarp. It includes two sections: one, represented by *Echium*, *Pulmonaria*, and other genera, has no ligular scales to the corolla; the other possesses them in greater or less prominence, the throat of the corolla sometimes being almost closed by them.

The character of the inflorescence in this order has given rise to some discussion. The view that it is a sympodial helicoid cyme is opposed by some, who prefer to consider it a unilateral raceme bearing usually two rows of flowers upon the upper side of the curved axis. It has been suggested, again, that in some at least of the order the branching is not lateral at all, but dichotomous; the growing point of the successive axes, after the first, dividing into two equal ones, one of which forms a flower, and the other again dichotomises.

Order 4. CONVOLVULACEÆ.—The plants of this order are herbaceous or shrubby, trailing or climbing by means of a twining stem. Some of them are leafless parasites without chlorophyll. The leaves are alternate and exstipulate. The flowers are regular; the calyx has persistent, almost free sepals; the corolla is twisted in the bud, the direction of the twist being to the right. In the *Cuscuteæ* it bears ligular scales (*fig.* 1214). The ovary is usually 2-celled, with two erect anatropous ovules in each cell. In some species a false septum divides each loculus into two, as in the last order, but the separation with four free lobes does not occur. In the *Nolaneæ* there are five or more carpels, which divide into a number of separate nutlets. The fruit is a capsule, with septifragal or occasionally transverse dehiscence, or in a few species a berry.

The order is divided into the following tribes:—

1. *Convolvuleæ.*—This tribe includes the twining herbs, which have usually a milky latex. The flowers are solitary, axillary; the corolla has the well-known trumpet shape and withers very quickly. In some species there is a bracteolar epicalyx (*fig.* 1212).

2. *Cuscuteæ.*—Parasites with no leaves. A twining stem surrounds closely such host plants as it attacks, and sends haustoria into their tissues. These plants are very degraded forms; they have no cotyledons to the embryo, which consists only of a cylindrical spirally coiled axis (*fig.* 1215). The seed germinates in the ground, producing a root with no root-cap, and a small plumule which continually circumnutates till it comes into contact with a host plant, round which it coils. The root soon perishes, and the little seedling establishes parasitic relations with the host. The flowers form close clusters, almost capitula. The *Cuscutas*, or *Dodders*, are parasitic on various host plants, frequently infesting Clover.

Fig. 1211.

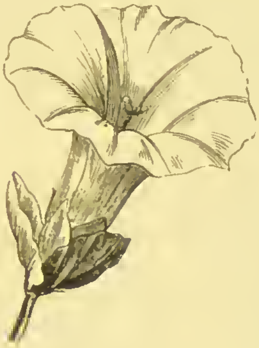


Fig. 1212.

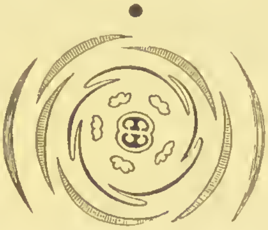


Fig. 1213.

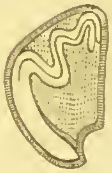


Fig. 1214.

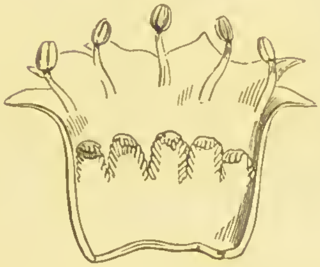


Fig. 1215.

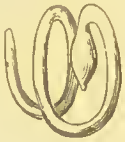


Fig. 1211. Flower of Great Bindweed (*Convolvulus sepium*).——*Fig.* 1212. Diagram of the same flower, showing two bracts on the outside of the calyx.——*Fig.* 1213. Vertical section of the seed of the same.——*Fig.* 1214. Corolla of Dodder (*Cuscuta*) laid open to show five epipetalous stamens and the scales in its tube.——*Fig.* 1215. Spiral embryo of a species of *Cuscuta*.

3. *Dichondreæ.*—The plants of this tribe do not twine, and are without latex. There are two free carpels.

4. *Nolaneæ.*—Carpels five or more, separating when ripe into a number of nutlets.

The plants of this order are chiefly remarkable for the presence of an acrid milky purgative juice in their roots; hence the order includes some important medicinal plants. In the roots of some species this purgative principle is either absent or in but small quantity. The seeds also of some species are purgative.

Order 5. SOLANACEÆ.—This order includes herbs, shrubs, and trees, the first-named preponderating. Their latex is not milky. Some of them are climbers, the mechanism being sensitive petioles (*Solanum*). The leaves are usually alternate and exstipulate, but in some species they are arranged in pairs, the leaves of a pair being of unequal sizes. This is due to displacement of the leaves. The inflorescence is cymose, but, like the branching of the stems, it is much complicated by displacement of the bracts, which are adherent for some little distance to the secondary axes, and hence appear to spring from the latter, instead of subtending them. The flowers are apparently regular, but are really zygomorphic in an oblique plane, the carpels being only two, which are not placed antero-posteriorly (*fig.* 1216). Zygomorphy is seen in the corolla in *Hyoscyamus*, and in the andrœcium in some other genera, the stamens differing in length and becoming almost didynamous. The pistil has two carpels, which form a 2-celled ovary with conspicuous axile placentæ carrying numerous seeds. The fruit is a capsule in some genera, a berry in others. The seeds have generally a curved embryo in fleshy endosperm.

FIG. 1216.

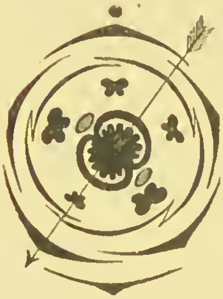


FIG. 1217.

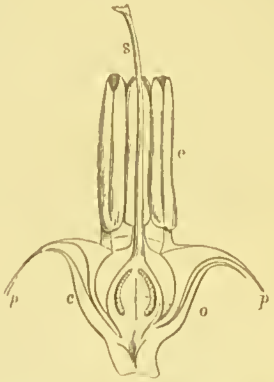


FIG. 1218.

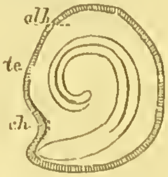


Fig. 1216. Diagram of flower of Petunia, showing the oblique symmetry.——*Fig.* 1217. Vertical section of the flower of the Potato (*Solanum*). *c.* Calyx. *p, p.* Corolla. *o.* Ovary. *e.* Stamens. *s.* Style and stigma.——*Fig.* 1218. Vertical section of the seed of *Solanum Dulcamara*. *te.* Testa. *ch.* Chalaza. *alb.* Endosperm, enclosing the curved embryo.

The order is divided into the following tribes :—

1. *Solaneæ.*—The fruit in the plants of this tribe is a berry. The embryo is curved. *Solanum* has syngenesious anthers, which dehisce by pores. *Atropa Belladonna* is the Deadly Nightshade ; it is the source of the drug *belladonna*. *Nicandra* has five carpels. *Physalis* bears a red accrescent calyx, which surrounds the fruit.
2. *Datureæ.*—The fruit is a capsule, which in some species (*Datura Stramonium*) becomes 4-celled from an outgrowth and displacement of the placentas. It has septifragal dehiscence. *Hyoscyamus* has a fruit which dehisces transversely ; it remains surrounded by a persistent calyx, which is globose at its base.
3. *Cestreæ.*—In this tribe the embryo is not curved. It includes *Nicotiana*, the Tobacco-plant. *Petunia* has zygomorphic symmetry (*fig.* 1216).
4. *Salpiglossideæ.*—This tribe approaches the *Scrophulariaceæ.* Its stamens are unequal n length, and some of them become staminodes. *Schizanthus* has much-dissected petals.

The plants of this order are nearly all poisonous in some part of their structure. The poisonous principle is generally narcotic. Some are pungent and stimulant, owing to the presence of an acrid oleo-resin ; others contain a bitter tonic principle. A few have edible fruits (*Lycopersicum*, the Tomato) or tubers (*Solanum tuberosum*, the Potato).

FIG. 1219.

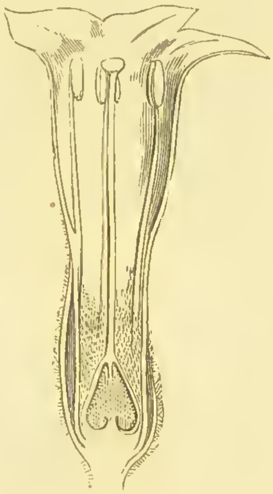


Fig. 1219. Vertical section of the flower of *Nicotiana.*

About 1,500 species are known, of which most are tropical.

Cohort 3.—*Personales.*

The plants of this group are generally heteromerous, suppression occurring in both andrœcium and gynœcium. The corolla is usually irregular, the stamens didynamous, or five, or two. The two carpels are placed antero-posteriorly ; the ovules are generally numerous.

Order 1. SCROPHULARIACEÆ.—These are herbaceous or sometimes shrubby plants with square or rounded stems bearing alternate or opposite leaves, without stipules. The flower bears a strong general resemblance to that of the *Solanaceæ*, but the zygomorphy is more conspicuous, almost always extending to the corolla and stamens. The corolla is frequently personate. The stamens vary in number; there are five in the *Pseudosolaneæ*, two in the genus *Veronica*, and four in the rest of the order, the arrangement being didynamous. In a few genera a staminode is found in the place of the fifth stamen. The pistil is like that of *Solanaceæ*, but the two carpels are placed in the antero-posterior plane. The embryo is straight, and the endosperm is abundant.

The order passes easily into the Solanaceæ, the connecting links being the *Pseudosolaneæ* of the present group and the *Salpiglossideæ* of the Solanaceæ.

The order is divided into the following tribes:—

1. *Pseudosolaneæ.*—The flower is nearly regular, and there are five stamens. *Verbascum*, the only British genus, shows very little irregularity in the corolla, which is rotate; the two anterior stamens are longer than the others.
2. *Antirrhineæ.*—The corolla is irregular, often personate, sometimes spurred; the stamens are four, didynamous, or only two. (*Calceolaria*, *Gratiola*). *Collinsia* has a papilionaceous corolla.
3. *Rhinantheæ.*—The flower is irregular, the stamens four or two. Many of the genera belonging to this group are symbiotic with other plants, their roots forming an attachment with those of the latter. They are frequently called *root-parasites*, but the evidence of parasitism is very slight. In *Veronica* the postero-lateral pair of stamens only are developed, and the corolla is apparently composed of only four petals, an appearance caused by the fusion of the two posterior ones (*fig.* 1220). The posterior sepal also is suppressed,

FIG. 1220.

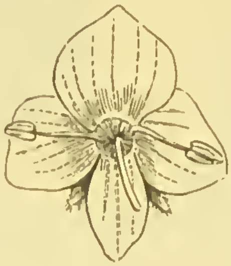


FIG. 1221.

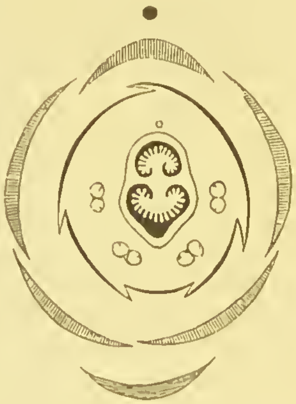


Fig. 1220. Flower of a species of Speedwell (*Veronica*).——*Fig.* 1221. Diagram of the flower of the Great Snapdragon (*Antirrhinum majus*), with one bract below.

The order comprises about 2,000 species, chiefly found in temperate climates. Several are poisonous, many are bitter, others astringent; some are purgative, emetic, or diuretic; a few are narcotic.

Order 2. OROBANCHACEÆ.—A small order of root parasites devoid of chlorophyll. They have succulent stems and scaly leaves. The structure of the flower differs but little from that of the *Gesneraceæ.*

Order 3. LENTIBULARIACEÆ.—The ovary is 1-celled, with a free-central placenta; seeds exalbuminous. There are only two stamens, the posterior three being suppressed. The plants are either aquatic or marshy in their habit, and many of them are insectivorous.

Utricularia is an aquatic form. Its finely divided leaves bear curious traps to catch small animals. They are bladder-like, with an aperture guarded by a small valve which opens inwards. *Pinguicula* is a marsh plant with rosettes of thick yellow leaves, the margins of which curve over when stimulated and enclose insects which alight upon them.

Order 4. COLUMELLIACEÆ.—A small order of evergreen shrubs or trees, natives of Mexico and Peru. They have an inferior ovary, surmounted by a fleshy disc.

Order 5. GESNERACEÆ.—A small order differing from *Scrophulariaceæ* chiefly in the structure of the ovary, which is unilocular, with two parietal placentæ. The ovary is inferior in the *Gesnerieæ*, superior in the *Cyrtandreæ.* The stamens are didynamous in the plants of the former section, but those of the latter have only two.

Order 6. BIGNONIACEÆ.—The plants of this order are nearly all arborescent; many of them are climbers (lianes), some having leaf-tendrils, others twining stems. The seeds are peculiar in being winged; they have no endosperm.

Order 7. PEDALINEÆ.—A small order of glandular herbs with entire exstipulate leaves and large irregular flowers. The ovary is seated on a large fleshy or glandular disc, and is usually unilocular, with two parietal placentæ.

Order 8. ACANTHACEÆ.—The plants of this order are generally herbs, but a few are arborescent. The branches are swollen at the nodes, and bear opposite simple leaves without stipules. The corolla is irregular, sometimes bilabiate; the stamens are didynamous or only two in number; the ovary is 2-celled, and the fruit a 2-valved capsule.

Cohort 4.—*Lamiales.*

The plants of this group have generally heteromerous flowers, suppression in the andrœcium and gynœcium being frequent. The corolla is irregular, frequently bilabiate; the stamens are four, didynamous, in consequence of the abortion of the posterior one; in some genera only two are present. A staminode sometimes represents the missing posterior stamen. The carpels are two, median; the bilocular ovary is in some cases divided into four loculi; each carpel or cell contains either a single ovule or two collateral ones. The plants have all exstipulate leaves.

Order 1. MYOPORINEÆ.—A small order of plants found chiefly in the southern hemisphere. It differs from the *Verbenaceæ* only in having two seeds in each cell of the fruit, and in its embryo having a superior radicle.

Order 2. SELAGINEÆ.—A small order of Heath-like plants, mostly African. The calyx is sometimes formed of two free sepals, though in most cases it is gamosepalous. The stamens are didynamous, and the ovary has two cells, each with one pendulous ovule. In some species one cell is suppressed. The fruit is a schizocarp dividing into two nutlets.

A small section of this order, the genus *Globularia*, is by some botanists considered as a separate order, *Globulariaceæ*. The flowers are arranged in capitula without any involucre, and the ovary is 1-celled only.

Order 3. VERBENACEÆ.—The plants of this order are herbs, shrubs, or trees, the shrubs preponderating; a few are climbers. The leaves are opposite in most cases, but not in all. The corolla is generally zygomorphic, sometimes slightly bilabiate, in some cases regular. The stamens are didynamous; and the ovary 1—2-celled, with two ovules in each cell. In most cases it is entire, but in a few it resembles that of the *Labiatæ*. The style is terminal. The fruit is either a schizocarp, splitting into two or four nutlets, or is drupaceous, the stone being 4-celled, or four distinct stones being present.

FIG. 1222.

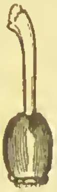


Fig. 1222. Pistil of the Vervain (*Verbena*).

Many of the plants of this order are slightly aromatic and bitter, but there are no important medicinal plants included in this order. Some are valuable timber trees (Teak); other species have fleshy fruits, which are edible; and the leaves of a few are used as substitutes for China Tea. Many are cultivated in our gardens for the beauty of their flowers or for their fragrance, as the different species and varieties of *Verbena*, the *Aloysia citriodora* (the Lemon-plant), &c.

Order 4. LABIATÆ.—The plants of this Natural Order are nearly all herbaceous, but there are a few shrubs and trees. They have a very characteristic appearance, the stem being always square, and the leaves opposite and decussate. The stem and leaves are generally covered with glandular hairs, which secrete an aromatic essential oil. When there are no hairs there are internal glandular reservoirs. The inflorescence is mixed, the flowers being grouped round the stem in opposite verticillasters, which are cymes, with almost sessile flowers. The terminal flower of the cyme gives off a flower on each side; each of these secondary axes bears only one flower on the side furthest from the central one; each of these again gives off another. There are usually seven flowers in each cyme. The cymes or verticillasters arise in the axils of a pair of ordinary foliage leaves. The stem bears a succession of these pairs of verticillasters, which are arranged racemosely, the youngest being nearest its apex. The flowers are zygomorphic, both calyx and corolla being bilabiate. The upper lip of the calyx consists of three sepals, that of the corolla of two petals. In some genera, e.g. *Mentha*, *Lycopus*, the zygomorphy of the corolla is very slight, and the flower consequently appears almost regular. The stamens are didynamous, the posterior one being suppressed. Occasionally, as in *Salvia*, only two stamens are present. The pistil is almost exactly like that of the *Boraginaceæ*, the only difference being that the embryo is directed downwards instead of upwards. There are two carpels, which by a spurious division form a 4-lobed ovary; this becomes four nutlets in the fruit;

Fig. 1223.

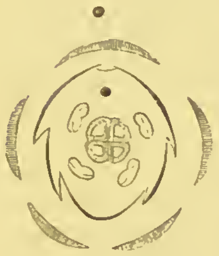


Fig. 1224.

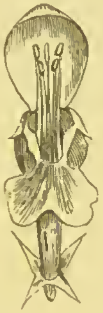


Fig. 1225.

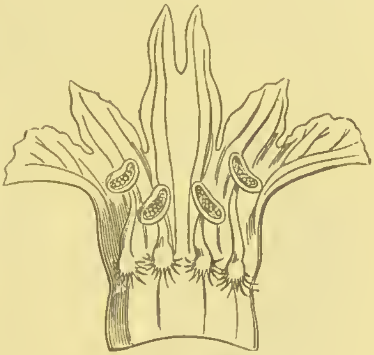


Fig. 1223. Diagram of flower of Lamium.——*Fig.* 1224. Front view of flower of Lamium.——*Fig.* 1225. Flower of Marrubium cut open.

Fig. 1226.

Fig. 1226. Pistil of Salvia.

the style is gynobasic. In the forms with sub-regular corollas the stamens are not didynamous, but spreading, as in the *Dipsaceæ*.

A few variations from this typical structure occur. The flowers in *Scutellaria* and *Origanum* are solitary and not arranged in verticillasters. There are only two stamens in *Salvia*, which are singular in shape. The filament is short and is joined to the middle of a very long connective, which is filiform and bears at one end a perfect anther-lobe, while that which should be at the other is modified into a disc-like body which lies in the throat of the corolla (*fig.* 1227). This is so placed that an insect in thrusting its proboscis into the flower causes the long connective to swing upon the filament like a lever on its fulcrum, so that the anther is pressed down upon the insect's back, a position which is assumed by the stigma later, when the anthers have finished their dehiscence.

Fig. 1227.

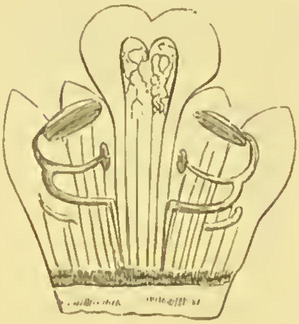


Fig. 1227. Flower of Salvia cut open to show the two stamens.

The British genera of the order are grouped into the following tribes:—

1. *Menthoideæ.*—The corolla is campanulate and nearly regular. The stamens are divergent.
2. *Monardeæ.*—The corolla is bilabiate; the stamens only two.
3. *Satureineæ.*—The corolla is bilabiate, and the four stamens are divergent; the connective is broad.
4. *Scutellarieæ.*—The corolla is bilabiate; the stamens didynamous, the inferior pair being the longest; the calyx is bilabiate, and closed in fruit.
5. *Nepeteæ.*—These differ from the *Scutellarieæ* in having the inferior pair of stamens shortest. The calyx is not bilabiate.
6. *Stachydeæ.*—These are like the *Scutellarieæ*, but the calyx is not closed in fruit, and in some species is not bilabiate; the corolla is usually ringent.
7. *Ajugoideæ.*—The corolla has its upper lip very short or deeply cleft, and appearing to be absent (*fig.* 1228).

Fig. 1228.

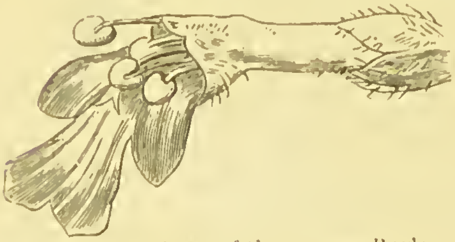


Fig. 1228. Flower of the common Bugle (*Ajuga reptans*).

There are two other tribes not represented by British plants:—*Ocimoideæ*, with four descending stamens; and *Melissineæ*, with didynamous stamens, which are widely separated at their bases, but converge upwards so that their anthers are closely approximated under the upper lip of the corolla.

The Labiatæ form a large order, there being about 2,700 species; they occur chiefly in temperate regions, particularly in the Mediterranean region. They are entirely free from any deleterious qualities. They abound in *volatile oil*, and are therefore commonly aromatic, carminative, and stimulant. All the plants of the order also contain more or less of a *bitter extractive matter*, and many of them possess an *astringent principle*, hence they are frequently tonic and stomachic. Several are used in perfumery on account of their agreeable odours; and many are employed by the cook for flavouring, such as *Thymus vulgaris* (Garden Thyme), *Thymus citriodorus* (Lemon Thyme), *Salvia officinalis* (Sage), *Origanum vulgare* (Marjoram), *Marjorana hortensis* (Sweet Marjoram), *Satureia montana* (Winter Savory), *Satureia hortensis* (Summer Savory), &c. The fleshy underground stems of *Stachys palustris* and of a species of *Ocymum* are edible.

Ordo anomalis.

Plantaginaceæ.—This is a small order of plants which by many botanists are held to be closely allied to the *Scrophulariaceæ*, and are consequently included in the cohort *Personales*. They are generally without aerial stems, and a rosette of leaves appears to arise from the crown of the root; the leaves are strongly ribbed. The flowers are usually arranged in spikes; they are sometimes diclinous (*Litorella*). The calyx and corolla are 4-partite, and the latter is dry and membranous and persistent. The stamens are four, with long slender filaments. The ovary is generally bilocular, and has a feathery style. The fruit is a pyxis; the placentation is basal or free-central.

The flower is developed similarly to that of *Veronica*, the posterior sepal and stamen being abortive, and the two posterior petals completely coherent. The suppression of the antero-lateral stamens, seen in *Veronica*, does not occur.

Artificial Analysis of the Orders in the Sub-class Gamopetalæ or Corollifloræ.

⁂ A few orders belonging to the Sub-class Polypetalæ, the flowers of which are sometimes gamopetalous, are also included in this analysis.

Ovary inferior.	
A. Ovary usually 1-celled.	
a. *Anthers united.*	
Ovule solitary, pendulous	*Calyceraceæ.*
Ovule solitary, erect	*Compositæ.*
b. *Anthers distinct.*	
Fruit with 1 perfect cell and 2 rudimentary ones.	
Seed exalbuminous	*Valerianaceæ.*
Fruit 1-celled, and without any rudimentary ones. Seed albuminous . . .	*Dipsaceæ.*
B. Ovary with more than 1 cell.	
a. *Anthers united.*	
Leaves alternate	*Campanulaceæ* (*Lobelieæ*).
b. *Anthers distinct.*	
1. *Stamens* 2.	
Filaments not united to the style . . .	*Columelliaceæ.*
Filaments united to the style	*Stylidiaceæ.*
2. *Stamens more than* 2.	
Anthers opening by pores or slits . . .	*Vacciniaceæ.*
Anthers opening longitudinally.	
Stigma with an indusium	*Goodeniaceæ.*
Stigma without an indusium.	
Leaves without stipules.	
Stamens definite.	
Leaves alternate. Corolla persistent	*Campanulaceæ.*
Leaves opposite. Stem round . .	*Caprifoliaceæ.*
Leaves verticillate. Stem square .	*Rubiaceæ.*
Leaves with stipules.	
Stipules interpetiolar. Flowers hermaphrodite	*Rubiaceæ.*
Ovary superior.	
Carpels more than 1.	
a. *Anthers opening by pores or slits* . . .	*Ericaceæ.*
b. *Anthers opening longitudinally.*	
1. Anthers 1-celled	*Epacridaceæ.*
2. Anthers 2-celled.	
Plants with dotted leaves	*Rutaceæ.*
Plants parasitic, leaves brown, scaly . .	*Monotropaceæ.*

A. Flowers regular.

a. *Ovary lobed.*

Inflorescence helicoid. Æstivation of corolla imbricate . . . . *Boraginaceæ.*

b. *Ovary not lobed.*

1. *Carpels more than 3, distinct or combined.*

Stamens equal in number to the petals and opposite to them.

Stems herbaceous. Style 1. Fruit a capsule . . . . *Primulaceæ.*

Stem woody. Style 1. Fruit fleshy, indehiscent . . . . *Myrsinaceæ.*

Stem herbaceous or woody. Styles 5 (rarely 3 or 4). Fruit membranous . *Plumbaginaceæ.*

Stamens not opposite the petals if of the same number.

Carpels combined. Ovary 2- or more celled.

Ovules erect or ascending.

Æstivation of the corolla plaited. Fruit dry . . . . *Convolvulaceæ.*

Æstivation of the corolla imbricate. Fruit fleshy . . . . . . *Sapotaceæ.*

Ovules pendulous or suspended, or rarely partly ascending.

Stamens twice or four times as many as the lobes of the corolla, distinct *Ebenaceæ.*

Some of the ovules occasionally ascending. Filaments more or less cohering . . . . *Styraceæ.*

2. *Carpels 3, combined so as to form a 3-celled ovary.*

Stem herbaceous. Disc hypogynous . . *Polemoniaceæ.*

Stem woody. No disc . . . . . . *Diapensiaceæ.*

3. *Carpels 2, combined or more or less distinct.*

Stamens 2 . . . . *Oleaceæ.*

Stamens 4 or more. Inflorescence helicoid.

Fruit a capsule, 1-celled or imperfectly 2-celled . . . . *Hydrophyllaceæ.*

Fruit drupaceous, 2- or more celled . { *Boraginaceæ* (*Ehretieæ*).

Stamens 4 or more. Inflorescence straight.

Leaves alternate.

Calyx in a broken whorl . . . . . *Convolvulaceæ.*

Calyx in a complete whorl.

Anthers united to the stigma . . . *Asclepiadaceæ.*

Anthers free from the stigma.

Placentas parietal . . . . . *Gentianaceæ.*

Placentas axile.
Æstivation of corolla valvate, induplicate - valvate, or imbricate . . . . . . *Solanaceæ.*
Leaves opposite, whorled, or clustered.
Anthers united to the stigma . . . *Asclepiadaceæ*
Anthers free from the stigma.
Leaves with stipules . . . . *Loganiaceæ.*
Leaves without stipules.
Stigma shaped like an hour-glass.
Æstivation of corolla contorted . *Apocynaceæ.*
Stigma not contracted in the middle like an hour-glass.
Æstivation of corolla imbricate, placentas parietal . . . *Gentianaceæ.*
4. *Carpel solitary.*
Stamens opposite the lobes of the corolla or petals . . . . *Plumbaginaceæ.*
Stamens alternate to the lobes of the corolla.
Fruit 1-celled. Stigma sessile . . . *Salvadoraceæ.*
Fruit spuriously 2-celled or rarely 4-celled.
Style capillary . . . . . . *Plantaginaceæ.*
B. Flowers irregular.
a. *Ovary 4-lobed* . . . . *Labiatæ.*
b. *Ovary not lobed.*
1. *Carpel solitary* . . . . . *Selaginaceæ.*
2. *Carpels* 2.
Fruit hard or nut-like.
Anthers 1-celled . . . . . . *Selaginaceæ.*
Anthers 2-celled. Ovules erect.
Corolla imbricate in æstivation . . *Verbenaceæ.*
Corolla valvate in æstivation . . . *Stilbaceæ.*
Anthers 2-celled. Ovules pendulous . . *Myoporineæ.*
Fruit capsular or succulent.
Placentas parietal.
Leafless scaly, brown, root-parasites . *Orobanchaceæ.*
Leafy plants. Seeds with wings . . *Bignoniaceæ.*
Leafy plants. Seeds without wings.
Fruit a capsule or baccate. Cotyledons minute, radicle long . . . *Gesneraceæ.*
Fruit bony or a capsule. Cotyledons large, radicle short . . . . *Pedalineæ.*
Placentas axile.
Seeds without wings.
Albuminous . . . . . . *Scrophulariaceæ.*
Exalbuminous. Seeds attached to hard placental processes . . *Acanthaceæ.*
Seeds winged. Exalbuminous . . . *Bignoniaceæ.*
Placentas free-central . . . . . *Lentibulariaceæ.*

There are many exceptions to the characters above given of the Gamopetalæ or Corollifloræ. Thus, among the Inferæ or Epigynæ we occasionally find polypetalous corollas in *Caprifoliaceæ* and *Lobeliaceæ*, and the ovary is sometimes superior in *Goodeniaceæ*. In the Superæ and Bicarpellatæ, polypetalous species are sometimes found in *Ericaceæ*, *Monotropaceæ*, *Epacridaceæ*, *Styraceæ*, *Oleaceæ*, *Primulaceæ*, *Myrsinaceæ*, and *Plumbaginaceæ*.

Again, among the Superæ and Bicarpellatæ we occasionally find the ovary inferior, or partly so, as in *Ebenaceæ*, *Styraceæ*, *Myrsinaceæ*, *Primulaceæ*; it is always so in *Gesneraceæ* and *Vacciniaceæ*.

In *Oleaceæ* and *Primulaceæ*, apetalous species sometimes occur; and diclinous species also are occasionally found in *Valerianaceæ*, *Compositæ*, *Ebenaceæ*, *Myrsinaceæ*, and *Plantaginaceæ*; and other exceptions have been already noted.

Synopsis of the British Natural Orders of the Sub-class Gamopetalæ.

A. Corolla gamopetalous, superior.	
Stamens inserted beneath epigynous disc	*Vacciniaceæ.*
Stamens inserted with the corolla and free from it.	
Filaments free	*Campanulaceæ.*
Stamens epipetalous, alternate with lobes of corolla.	
Anthers united, flowers in capitula	*Compositæ.*
Anthers free.	
Inflorescence a capitulum. Calyx with involucel	*Dipsaceæ.*
Flowers corymbose or cymose.	
Fruit with a double indehiscent pericarp, 2-celled, 2-seeded	*Rubiaceæ.*
Fruit dry, with 1 perfect and often 2 abortive cells	*Valerianaceæ.*
Fruit fleshy, with 1 or several seeds	*Caprifoliaceæ.*
Corolla gamopetalous, inferior.	
Ovary and fruit 4-lobed. Style gynobasic.	
Stamens 5. Corolla regular. Leaves alternate	*Boraginaceæ.*
Stamens 4 or 2, corolla irregular, leaves opposite	*Labiatæ.*
Ovary and fruit simple. Style terminal.	
Ovary 1-celled, 1-seeded. Stamens antipetalous. Styles 5	*Plumbaginaceæ.*
Ovary 1-celled, many-seeded.	
Corolla scarious, regular. Stamens 4	*Plantaginaceæ.*
Corolla coloured.	
Corolla irregular.	
Stamens 2	*Lentibulariaceæ.*
Stamens 4, didynamous	*Orobanchaceæ.*
Corolla regular. Stamens antipetalous	*Primulaceæ.*

Ovary 2- or more celled (fruit sometimes 1-celled).	
Stamens hypogynous, distinct	*Ericaceæ.*
Stamens epipetalous.	
Stamens 2. Corolla regular . . .	*Oleaceæ.*
Stamens 2 or 4, didynamous. Corolla irregular.	
Ovary 2-celled, not lobed. Placentas axile	*Scrophulariaceæ.*
Ovary 2—4-celled, lobed	*Verbenaceæ.*
Stamens 4 or 5, not didynamous.	
Cells of ovary each with 1 or 2 ovules.	
Fruit a capsule	*Convolvulaceæ.*
Cells of ovary each with many ovules.	
Fruit a double follicle	*Apocynaceæ.*
Fruit 2- or imperfectly 4-celled. Leaves alternate	*Solanaceæ.*
Fruit 1- or imperfectly 2-celled. Leaves opposite	*Gentianaceæ.*
Fruit 3-celled . . .	*Polemoniaceæ.*

BOOK IV.

PHYSIOLOGY OF PLANTS.

CHAPTER I.

THE RELATION OF WATER TO THE PROTOPLASM OF THE CELL.

WE have already seen in considering the structure of both simple and complex plants, that they are all composed originally of a variable number of protoplasts, which are in close relationship with each other, being partially separated in most cases by septa, or partitions, known as cell-walls. The latter show a great deal of variety in the way they are arranged, their thickness, the material of which they are composed, &c. The protoplasts, on the other hand, resemble each other in all essential particulars, though in complex plants one or other function or property of each is often developed to a greater extent than the remainder which it possesses.

The essential difference between the protoplasm of the plant and the walls by which it is supported lies in the fact that the former is the living substance, by whose activity all the remainder is constructed. In dealing with the physiology of the plant, we have therefore to turn our attention to the protoplasm. We have seen that in the simplest forms of plant this may exist without any cell membrane, and may be freely motile, swimming in water by means of cilia, or creeping in a semi-animal fashion by pseudopodia. In other unicellular plants it may be surrounded by a cell-wall, and may either entirely fill the space afforded inside the latter, or may have inside itself a vacuole. In the multicellular plants, each cell while living shows its own protoplast or aggregation of the protoplasm, which is probably connected always with that of the adjoining cells. The protoplasm generally lies as a peripheral layer round the outside of the cell, though in many cases the central cavity is crossed by a number of bridles passing generally from a somewhat central spot to the periphery. Except in a few Thallophytes a nucleus is a constituent of all cells when they are young, though rarely it disappears later. It is always embedded in the protoplasm, of which it is a specially differentiated portion.

Not only does the living substance construct the substance of the plant originally, but it is the part by which the organism is able to place itself in harmony with its environment. It assimilates the food the plant requires and carries out the chemical processes incident to its life ; it receives impressions from without and regulates the response the plant makes to these impressions, both by internal and external movements or changes of position ; finally it carries out the reproductive processes.

Looking at the arrangement of protoplasm in the cell, or at its environment in the free condition, we notice especially its very close relation to water. The free-swimming zoospore is naturally saturated with the latter, being in the fullest contact with it. The young cell enclosed in its cell-membrane speedily shows a tendency to accumulate water in its interior, and gradually drops appear, which lead ultimately to the formation of a vacuole always full of liquid. The healthy protoplasm is thus always in contact with water. Indeed the molecular constitution of protoplasm, as far as we know it, lends itself to this relation, for the apparently structureless substance is always saturated with it. It is only while in such a condition that the cell can live ; with very rare exceptions, if a cell is once completely dried, even at a low temperature, its life is gone, and restoration of water fails to enable it to recover.

The constancy of the occurrence of the vacuole in the cells of the vegetable organism is itself an evidence that such cells depend upon water for the maintenance of their life. The cell-wall, though usually permeable, yet presents a certain obstacle to the absorption of water, and so even those cells which are living in streams or ponds usually possess a vacuole. Cells without a membrane, such as the zoospores already many times mentioned, can more readily absorb water from without, and hence they are not vacuolated to the same extent as the former ones ; indeed, many of them have no vacuole. This cavity being always filled with liquid, the protoplasm of the cell has ready access to water, as much so indeed as the cell which possesses no wall. The vacuole contains a store which is always available.

We have seen that the presence of water is necessary to the life of the cell, and that a store of it is usually contained in its interior. As this must be absorbed from without, it becomes necessary to inquire into the way in which it effects its entry. This is based upon a purely physical process which is known as *osmosis.* If two fluids of different densities, for example water and syrup, be separated from each other by a homogeneous permeable membrane, they will tend to pass through the latter till there is a mixture of the two of equal density on each side of it. We shall thus have a stream of water passing through the membrane to the syrup, and a stream of syrup similarly passing to the water. The rate of flow of the two streams will not be the same, however, and the first result will be a considerable increase in quantity of the fluid upon the side of the membrane in contact with the syrup, owing to the greater amount of water that will have passed through.

A convenient form of apparatus to exhibit this process of osmosis is shown in *fig.* 1229. It consists of a bladder fastened to the end of a narrow tube, which is immersed, as shown, in a vessel of water. The bladder and part of the tube are filled with syrup, and the height at which the latter stands in the tube is noted. After some time the contents of the tube will be increased, and the liquid will stand in it at a higher level, in consequence of the osmotic action that has taken place. If the positions of the water and the syrup were reversed, the liquid would fall in the tube, showing that under these conditions also there is a greater stream of water towards the syrup than of the latter in the opposite direction.

FIG. 1229.

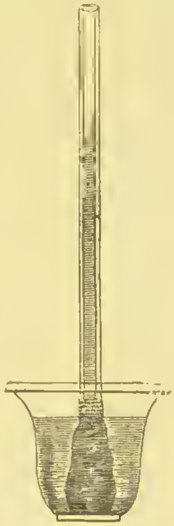


Fig. 1229. Apparatus to show *osmotic action.* It consists of a bladder filled with syrup to the open end of which a tube is attached, and the whole placed in a vessel containing water.

Though the process thus stated is far simpler than what we have reason to believe takes place in the vegetable cell, we can apply it to explain the original formation of the vacuole. Consider the case of a cell of the dermatogen of a plant which is immersed in water. It is full of protoplasm, and limited or clothed by a cell-membrane, which is permeable more or less readily by water. The protoplasm is saturated with water, but there is no separate accumulation of the latter. Part at least of the cell-wall is in contact with water on the outside. The protoplasm is actively living, and in the course of the chemical changes which are incident to vital action, certain substances are produced by it, which, like the syrup in the experiment detailed, have an affinity for water, or, to use a more technical phrase, have a fairly high osmotic equivalent. Water consequently passes into the cell, at first only in such quantities as to somewhat distend it. As the process goes on, more liquid is present than can be stored in the molecular interstices of the protoplasm. Drops consequently appear, and these gradually run together until a distinct though small vacuole, or a number of such vacuoles, is apparent in the protoplasm. By a continuation of the process the protoplasm ultimately forms a layer round the cell-wall, enclosing the large cavity in which the surplus liquid is held.

But, as has already been said, the process is not a simple physical one. Though the conditions of the first experiment are approximated to, they are not altogether realised. The syrup in the bladder finds its representative in the osmotic substances formed by the protoplasm and dissolved in the water in its meshes; the water outside the cell is the same as the water in the outer vessel. But there is a great difference in the membrane. The bladder of the experiment is replaced by a film of cellulose lined by the protoplasm itself. The former is readily permeable, but the latter is not. A further experiment will show a very important modification of the process, brought about by the protoplasm, and demonstrating that the entry of water into the cell is very largely under the regulation of the latter.

Take a cell of the cortex of the plant and put it in contact with a liquid of higher osmotic power than its own contents; for instance with a solution of common salt, containing 5 to 10 per cent. of the crystals. Watch its action on a slide under the microscope, and let the salt solution be coloured with some vegetable dye which will not injure the living substance. As the salt solution reaches the cell, the protoplasm of the latter gradually retreats from the walls, at first at the corners and then all round the sides, till it appears as a rounded mass in the centre. The salt solution has abstracted the water from the vacuole, and the protoplasm, relieved of the outward pressure caused by the liquid in the latter, has shrunk away from the walls. The outward stream has been accompanied by an incoming one as in the first experiment. The coloured salt solution will be seen inside the cell-wall, between it and the protoplasm. But here is a great difference between the two experiments; the salt solution does not pass through the protoplasm, though it does go through the cell-wall. If, now, the salt solution be replaced by water, the latter is gradually attracted again, of course osmotically, into the cell. It passes through the protoplasm; the vacuole is re-established, and the protoplasm again comes to line the cell-wall, pressed against it by the water.

The protoplasm thus allows water to pass through its substance, but can oppose the passage either way of the various osmotic bodies with which it may be brought into contact. In the last narrated experiment it prevented the salt solution from entering the vacuole, and, as shown by the return of the water into the latter, it prevented the osmotic substances originally in the cell from leaving it.

That this is due to the vital power of the protoplasm can be shown by repeating the experiment after killing the living substance by a short immersion of the cell in alcohol. Then the process of osmosis goes on exactly as in the first experiment quoted. The salt solution penetrates into the vacuole as if only a cellulose septum were present, the dead protoplasm exerting no regulating influence.

The modified osmosis, which is thus the mode of entry of water into a cell containing no vacuole, continues after the vacuole is formed, and is the cause of the transfusion of water from cell to cell. We can see that this must be the case, for if two cells are considered which are separated from each other by a common cell-wall, it is evident that, unless the proportion of water to osmotic substances in the vacuoles of both is the same, osmotic currents will flow from one to the other till this equilibrium is reached.

The quantity of osmotic substances present in any cell will depend upon the behaviour of the protoplasm from time to time. Such substances are usually being continuously produced in all growing cells and in most others in which chemical changes are proceeding. Hence such cells are constantly absorbing water, and are consequently so full that a certain stretching force is exerted on the cell-wall which bounds them. Cells in such a condition are called *turgid*, and the condition itself is known as *turgescence*. The equilibrium, which is attained by such a cell, is reached when the distension caused by the osmotic substances is balanced by the elastic recoil of the extensible cellulose wall. In some cases the tension set up in a tissue by the turgescence of the cells is sufficient to force the water, by a process of filtration, through the walls of the outermost ones, so that it escapes in drops or in a slow stream. This may often be seen on the edges or apices of blades of grasses in the early morning. It is of great use also in forcing water into the axial woody cylinder of roots, as will appear later. Occasionally the turgescence becomes so great as to lead to rupture of the cell-walls, as is the case sometimes in fleshy fruits.

That the condition of turgidity in cells is attended by a stretching of the cell-walls can be seen by taking a piece of a plant which is turgid, such as the stalk of a rhubarb leaf, and, after carefully measuring its dimensions, steeping it for some time in a 10 per cent. solution of salt. On removing it, it will have become flaccid, and a remeasurement will show that both its length and thickness have diminished. Turgescence is not, however, solely due to physical causes; the protoplasm which lines the cells has a regulating influence over the passage of the water in and out of the cell. If a turgid pulvinus of such a plant as *Robinia*, or *Mimosa*, be stimulated by rough handling of the leaf, the latter falls from its expanded position towards the stem, and the fall is found to be due to the escape of water from the cells of the lower side of the pulvinus. The original state of equilibrium has been disturbed by the shock to the protoplasm administered by the stimulation, and the latter allows water to pass outwards.

The active influence of the protoplasm is seen also in another class of phenomena. Certain structures known as nectaries have been described as occurring in many flowers. These are aggregations of cells of a particular kind which exude a sugary fluid upon their surfaces. If the petals of certain flowers bearing these nectaries be cut off and their cut ends immersed in water, the glands continue for some time to exude the nectar. There can be no question here of any filtration of water through the tissue, as there is no pressure acting on the base of the petal. The protoplasm causes the stream to continue to flow by producing osmotic substances, in this case chiefly sugar. It differs still more in its behaviour in that it pours out not only the water thus absorbed, but a certain amount of the sugar in addition. If the gland be killed by alcohol, the sugar already there is retained in the cells, and no exudation of nectar or even of water takes place.

The vital activity of the protoplasm is thus seen to be intimately connected with the presence of water in its substance. The importance of the ready access of the latter is seen further from other considerations. In the foregoing pages we have spoken of it as if it were pure water only; this is, however, not the case, for the water, when absorbed, contains small quantities of various substances in solution. Though the protoplasm opposes the entry of anything like a strong solution of inorganic salts, say 5 to 10 per cent., it allows very dilute ones to enter much as it does pure water. In this way the slowly diffusing stream brings to the protoplasm of each cell the inorganic materials which are absorbed from the earth, and enables the matters elaborated or formed from them by the protoplasm to pass from cell to cell. The feeding or nutrition of the various cells is thus dependent on the transit of fluid about the plant in the way described. The access of various gases is similarly made possible, for these are dissolved in the liquid stream. Thus the oxygen, upon the presence of which life depends, is transported to each cell, and the carbon dioxide of respiration is removed from the seats of its liberation. The condition of turgescence is necessary also for growth and for various movements of different parts, enabling them to adapt themselves to varying conditions of their environment. Some plants, particularly those which are aquatic in habit, and such parts of terrestrial plants as have but little woody tissue, are dependent upon the turgidity of their cells for the rigidity which enables them to retain their positions in the medium in which they live.

The importance of the water supply, and, indeed, its necessity to the plant, explains the presence of the aqueous tissue which we have seen to occur in various parts. The cells of this tissue contain little else than water, and may be regarded as an additional reservoir, supplementing the vacuoles of the ordinary cells. In plants that inhabit dry arid soils, such as sandy deserts, there are often other adaptations relating to water storage. Such plants are often covered with large bladder-like hairs, which hold a considerable quantity of liquid. In many plants the epidermal cells form a further reservoir. Plants exposed to conditions threatening too copious evaporation are generally furnished with a very prominent cuticle, tending to check undue escape.

CHAPTER II.

THE TRANSPORT OF WATER IN THE PLANT.

We have seen that it is necessary for the life of the plant that all its living cells shall be freely supplied with water. According to the habit of life of plants the mode of supply must necessarily vary. Those which are so constituted that water finds free access to all the cells, such as the unicellular or filamentous Algæ, which live in streams, pools, &c., present no difficulty, as osmosis can go on freely in each cell. Sturdier plants of aquatic habit are almost equally easily supplied; the water enters by osmosis into the epidermal cells, which we have already seen are provided with membranes that are not cuticularised, and it can pass readily from cell to cell all over the plant body. Plants of terrestrial habit, from the nature of their environment, require a more elaborate mechanism, which is found in the large development of woody tissue they exhibit. Throughout all such plants a stream of water passes, entering in at the roots, passing along the woody axis of the root, up the stem into the leaves, where a very large part of it is evaporated. This stream of water is often known as the *ascending sap*. In addition to this comparatively rapid stream, slow currents of diffusion from cell to cell are also maintained as in the plants of humbler development.

Except in some special cases, the water which passes through the body of an ordinary land plant is obtained from the soil in which its roots are embedded. The soil itself is composed of minute particles of inorganic matter, derived originally from the breaking down of rocks, and of decaying animal or vegetable matter mixed with the inorganic constituents. This organic matter is known as *humus* and is of very varied composition. The soil thus consists of a loose matrix of granular character, the interstices of which are normally filled with air, but which can contain varying quantities of water. When these spaces are filled with water, the plants growing in the soil are very unfavourably placed for absorbing it. When air is present in them, each particle of soil is surrounded by a delicate film of water, which adheres closely to it. This water, often spoken of as *hygroscopic* water, is the source of the plant's supply. It adheres so firmly to the soil particles that it escapes ordinary observation; if, however, soil which has been allowed to dry at any moderate temperature till its interstices are apparently empty be exposed to a heat approaching that of boiling water, a considerable quantity of vapour will be given off, due to the volatilising of the hygroscopic films.

We have seen that the youngest roots and rootlets are furnished near their apices with a number of delicate hairs (*fig.* 1230) or outgrowths of their epidermal cells (*fig.* 1231), which make their way into the interstices of the soil. Not only do these play a very important part in anchoring the plant to the substratum, but they are the means by which the water is absorbed. The delicate walls of these root-hairs come into the closest relationship to the particles of soil, pressing in some cases so closely upon them, that the particles are embedded in the membrane. The hygroscopic film of water is so separated from the interior of the root-hair by a most delicate pellicle of almost pure cellulose. The cell-sap in the hair contains a certain amount of acid in solution, and by virtue of this osmosis is set up. The root-hairs, which are very numerous, become turgid, and by continued osmosis the water is passed inwards to the cortex of the root, all the cells of which soon exhibit considerable turgescence, thus causing a great deal of hydrostatic pressure in the cortex. At the places where the latter abuts upon the xylem elements of the stele a filtration under this pressure takes place, so that the water is forced into the axial woody tissue.

FIG. 1230

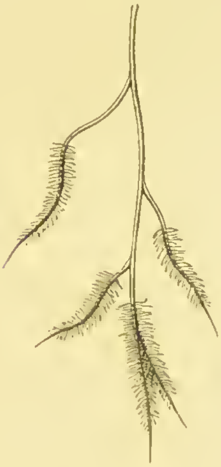


FIG. 1231.

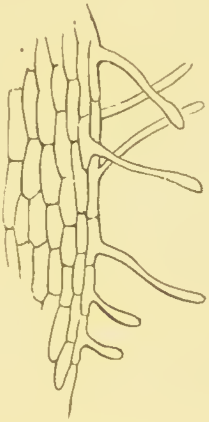


Fig. 1230. Ultimate branches of a root, showing position of root-hairs.——*Fig.* 1231. Root-hairs on the surface of a young root.

The filtration when set up tends to relieve the pressure in the cortex, and additional water can then be absorbed as before. The water is thus made to rise gradually in the axial stele, for the root-hairs and the cortical tissue exert together in this way a kind of pumping action, forcing it along the axis. This force, due to the turgescence set up as described, is known as *root-pressure*, and is one main factor in the transport of water through the plant. The turgescence not only leads to the rise of sap in the axial stele, but spreads throughout the whole of the cortical tissue of the plant, reaching indeed every cell into which osmotic diffusion can take place.

The stele of the root we have seen to be directly continuous with that of the stem, the woody elements being in contact throughout. The stream of water consequently passes up the woody tissue of the stem so long as the cells are living. The hard dead wood of the duramen takes no part in the conduction, which is confined to the alburnum. Some discussion has taken place as to the exact path followed, but that the one indicated is that which is taken has been proved by cutting incisions round the trunks of trees to various depths. So long as the alburnum is not cut the stream is not interrupted, but if the wound passes through that region it stops, and all parts of the tree above the incision droop and die.

The water has been said by some observers to pass along the cell-walls of the woody vessels and tracheïds, and not through their interior. Other writers hold that the main stream travels along the interior of the cells. To this point we shall return later. In either case the water ascends through the trunk, branches, and twigs of the tree till it reaches the points at which the foliar meristeles leave the central axis. It passes along the woody elements of these, entering the leaves thus by the fibro-vascular bundles or veins. From these it makes its way to the parenchymatous mesophyll of the leaves, the cells of which are thus made turgid. Osmotic diffusion, interrupted in the axis of the plant, is resumed in the leaves, and a general equilibrium of turgescence is reached in them.

We have seen that the parenchyma of the leaves, and particularly that of the lower half of each, is abundantly supplied with intercellular spaces (*fig.* 1232). The cells which abut upon these spaces are furnished with very delicate walls and readily allow a process of evaporation to take place, watery vapour passing into these passages. The surface of the leaf we have seen to be furnished with a number of openings or stomata, each communicating with the system of intercellular spaces, and having two guard-cells surrounding it. Through these stomata the watery vapour evaporated into the intercellular spaces passes to the external air, the quantity escaping being regulated by the degree to which the guard-cells are approximated. We have thus a copious evaporation taking place from the surface of the leaves, which plays an important part in causing the flow of water through the plant. This evaporation is known as *transpiration* and must be discussed more fully later.

Little or no evaporation takes place from the surface of the epidermis of the leaves, the cells of which have their outer walls generally strongly or weakly cuticularised, the cuticle offering considerable resistance to the passage of water, or watery vapour, in either direction.

The escape of water is thus mainly brought about by evaporation into the intercellular spaces of the leaves. It is not confined, however, to these, but takes place generally into all the intercellular spaces, which form a system of minute channels permeating the whole plant. The actual escape from the plant takes place wherever there are stomata, as well, that is, from the young green twigs as from the leaves themselves. It is supplemented in some cases by an actual excretion of water as such, carried out by means of the water glands we have seen to occur in some plants at the ends of some of the veins of the leaves. When the hydrostatic pressure is very high at times in herbaceous plants, water may be forced out of the tips of the leaves without the intervention of glands.

FIG. 1232.

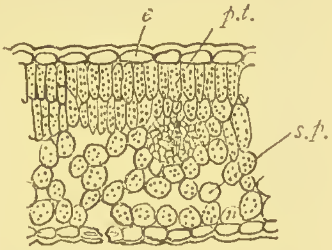


Fig. 1232. Section of leaf of *Beta*. *e*. Epidermis. *p.t.* Palisade tissue. *s.p.* Spongy parenchyma with large intercellular spaces.

The stream of water thus passing through the plant has a very important influence upon its development. This is evident from the consideration that a large part of the food of the plant is absorbed by means of this stream, the water containing minute proportions of the various nutritive salts which exist in the soil. The quantity passing is further correlated with the amount of leaf surface which the plant presents; where there is a large leaf area there is copious transpiration; this necessitates a larger path for the ascending stream and a consequent development of the axial portions of the plant. Where there is a large flow of water, as in a tree, there is a continuous formation of material; where the transpiration is but slight, as in a Cactus, there is but little formation of new plant substance.

CHAPTER III.

THE SKELETON OF THE PLANT.

We have seen that the protoplasm of the plant is a soft almost jelly-like substance, incapable of resisting any considerable disturbing force or pressure, such as almost all plants are inevitably exposed to, whatever be the nature of their environment. To enable them to cope with the difficulties presented by the latter, plants must possess a certain rigidity, which varies with the nature of their situation. The soft protoplasm must consequently be supported by something which will secure this rigidity. The several protoplasts are in most cases surrounded by a cell-wall or membrane which subserves this purpose. According to the habitat of each plant the development of its cell-membranes shows various degrees of complexity, and many modifications of the original structure are found. We have already seen that such modifications take the forms of alteration of the shape of the cell, of aggregations of cells in various ways, and of differences of chemical constitution brought about as the age of the cell increases. These differences are not merely connected with the maintenance of rigidity, but subserve also various functions which the different tissues of complex plants perform.

In the simplest plants, consisting of single cells, or rows or plates of cells, and living in water, but little rigidity is needed. The unthickened cell-wall is here sufficient, when combined with the turgescence of the cells, to prevent their being destroyed by the ordinary antagonistic influences which they have to encounter. The form of the plant is also modified to enable it to survive such difficulties. Plants growing in rapidly flowing water usually have flexible stems and much-divided leaves, which consequently give way to the current and escape damage. Those of terrestrial habit, on the other hand, exposed to winds and storms, are furnished with considerable development of woody roots which anchor them securely to the earth, and with sturdy trunks consisting of masses of wood, which secure stability even when atmospheric disturbances are severe. The subdivisions of the trunk, ending in finely divided twigs, while exposing considerable surface to the air, present on the whole a fairly yielding plant body, through which the currents of air can make their way without meeting such a resistance as to cause the uprooting of the tree. In other forms a weak stem of considerable length exists, which obtains support by clinging in various ways and holding by various mechanisms to some other structure, such as the trunks of trees, rocks, walls, &c. In these the woody development, though considerable, is much less than in ordinary trees.

The leaves show similar adaptations of structure to environment. The venation of the leaves, though mainly subserving the purpose of transport of liquids, is yet often such as to afford considerable resistance to damage from strong winds. Frequently the veins are so arranged as to form a series of arches on the external margins, preventing lateral tearing. The epidermal cells of many leaves often exposed to intense cold are strongly cuticularised, and the rigidity thus afforded is sometimes supplemented by a development of hypodermal sclerenchyma.

All these arrangements may be regarded as affording a supporting skeleton to the plant, the nature of which and the degree of its development can only be understood by a consideration of the habit of life of the plant under examination and the dangers to which its environment exposes it.

The ordinary cell-wall of the cell as it is first formed is a clear, transparent, extensible, and elastic membrane, which is secreted by the protoplasm and which remains in contact with it so long as the cell is living. It is capable under certain conditions of absorbing comparatively large quantities of water, and in consequence swelling considerably. It is usually said to be composed of a substance named *cellulose*, whose chemical composition is represented by the formula n $(C_6H_{10}O_5)$, the value of n not yet having been exactly determined. This substance is related to such bodies as starch, sugar, &c., being a member of the group of *carbohydrates*. It is capable, under the action of certain reagents, of being converted into a form of sugar, and under particular circumstances it can yield nutritive material for the use of the living substance.

Probably, however, the cell-wall is in very few cases altogether composed of pure cellulose, but mixed with the latter, certain bodies occur which are compounds of pectic acid with lime. There are many such bodies, but our knowledge of them is very imperfect, nor is their respective distribution at all well understood. Certain solvents will extract them from ordinary cell-walls, leaving cellulose as the basis of the latter.

The reactions of cellulose have been already described in an earlier section in dealing with the composition of the cell-wall. The most characteristic one is the assumption of a blue colour when treated with iodine and some hydrating agent, such as strong sulphuric acid or chloride of zinc.

Cellulose itself is capable of existing in more than one condition. We find some kinds of it which will stain blue on treatment with iodine alone. Examples are found in the cell-walls of the bast of the stele of Lycopodium, the endosperm of the Pæony, the cotyledons of some of the Leguminosæ, &c. The walls of the hyphæ of the Fungi differ again, in that they will not give the blue colour with iodine even after treatment with hydrating agents. Recent observations suggest that this variety of cell-wall approaches in composition the chitin of the animal kingdom.

It is probable that cellulose is chemically combined with a certain amount of water, and that the degree of hydration differs in the different varieties described.

Where considerable rigidity of structure is needed it is obtained by the conversion of the cellulose into *lignin*, the material found conspicuously in the walls of wood cells. This is formed in the substance of the cell-walls, and in partially lignified membranes the lignin can be dissolved out, leaving a cellulose basis. In its chemical characters lignin differs materially from cellulose; it has no extensibility, nor can it absorb water and swell as can the latter; on the other hand it allows water to pass through it with great rapidity and ease. It can be recognised micro-chemically by staining red when treated with phloroglucin and a mineral acid, or yellow with aniline chloride under the same conditions.

Lignin is probably not a definite chemical compound, but a mixture of substances successively formed from the cellulose. Its physical properties render it particularly adapted to serve as the material of which the tissues conducting the stream of water are composed. Its lack of flexibility or extensibility makes it suitable for the securing of rigidity in tissues or structures needing strong power of resistance to winds or storms.

The modification of the tegumentary tissue of the higher plants takes the form primarily of the transformation of the cell-wall into *cutin* or *suberin*, the former being characteristic of the outer layers of the epidermal cell-walls, and leading to the peculiar properties of the cuticle. Suberin is the substance found in great proportion in the walls of corky cells. Both of these are formed, like lignin, by modification of cellulose. They serve rather to prevent undue evaporation than to act as a true skeleton. In old trees, however, the complex barks, into the composition of which cork enters to a very considerable extent, often subserve somewhat the purpose of aiding in the mechanical support of the tree, especially in cases where the woody centre decays and the tree becomes hollow.

In many cases the cell-walls, while remaining chemically unchanged, become impregnated with silica or other mineral matter. The cereal grasses and the Equisetaceæ accumulate copious quantities of silica in the walls of their epidermal cells. Though this appears not to be altogether essential to their power of remaining upright, it no doubt materially assists it.

Other modifications of cellulose are found in various cell-walls, but they are comparatively unimportant from the point of view now under discussion.

Where the ordinary unmodified cell-walls of the plant are not sufficient to secure rigidity, as in most terrestrial plants, there is a very varied distribution of tissues for that purpose. The forms which are found are collenchyma, sclerenchyma, and vascular tissue, the former two appearing to subserve mechanical purposes only, while the latter also takes part in the transport of water. In delicate stems but little development of either is seen; thus most moss plants show in their axis only the hypodermal cells thickened, while this is supplemented in the *Polytrichaceæ* by a central core of somewhat lignified cells. In succulent petioles there is a hypodermal development of collenchyma, in addition to the meristeles, which contain a certain amount of wood. In many herbaceous stems, particularly those with angles, strands of sclerenchyma are found underlying part or the whole of the margins. In many Monocotyledons of humble growth the centre of the stem is hollow or is occupied by thin-walled fundamental tissue, sometimes made of stellate cells, and the margin is strengthened by strands of sclerenchymatous fibres placed behind or between the fibro-vascular bundles.

Plants of larger growth depend very greatly on the fibro-vascular part of the stele for their supporting tissue. This is seen most easily in the trees belonging to the Gymnosperms and Dicotyledons, which increase regularly in thickness. Large monocotyledonous trees depend upon the same class of elements, though the distribution of the individual bundles is different.

In many members of these groups, and in many of the Pteridophytes, the fibro-vascular system is not so well developed, and we find in such plants that the stereome is supplemented by the appearance of bands or sheaths of sclerenchyma very variously disposed. There is usually a considerable hypodermal development, besides masses occurring more deeply in the axis. Sometimes the cortical ground tissue contains isolated sclerenchymatous bands, often of large size; frequently the pericycle has similar developments. Sometimes, again, the sclerenchyma, instead of being in isolated strands, forms a continuous ring or sheath. Many stems contain developments in all three regions which are variously connected together.

The arrangements of stereome tissue in the leaves are similarly varied. The meristele of the petiole is frequently found to have a large amount of sclerenchyma in its pericycle, and this is continued upwards along the chief axis or axes of the epipodium, gradually thinning out as the margin is approached. In the large flattened leaves of some Monocotyledons, bands of sclerenchyma frequently extend completely across the interior. In some leathery leaves large idioblasts of various form act as struts or trabeculæ, reaching from one epidermis to the other. The arrangement of the veins in many leaves has already been alluded to.

The root usually depends for its rigidity upon the great development of fibro-vascular tissue in the stele. As we have seen, the tissues external to the endodermis are not as a rule long-lived, and hence the bulk of an adult root is stelar in origin. Aquatic roots, like the stems of the same plants, have but little development of specially supporting tissue, but owe their rigidity to the turgescence of their cortex.

CHAPTER IV.

THE TRANSPIRATION CURRENT—ROOT-PRESSURE—TRANSPIRATION.

We have seen in Chapter II. that in terrestrial plants, so long as circumstances are favourable to the vital activity of the organism, a stream of water is passing from the roots through the axis to the green twigs and leaves, where the greater part of it is evaporated. This current has been called the *transpiration* current, and its rate has been ascertained to be on an average about 100 centimetres per hour. The path by which it passes has been shown to be the young wood of the axial stele, into which it is forced by a kind of filtration from the over-turgid cortical tissue of the root. The wood vessels and tracheïds form a closed system, quite separated from the atmosphere, containing air and a certain quantity of water. Sometimes they are filled with the latter, often they contain a much larger quantity of air. In no case probably are they during life free from either, though the proportions of the two vary very greatly. Much controversy has arisen as to whether the transport of the water takes place through the substance of the cell-walls or through the cavity of the vessels and tracheïds. The character of the cell-walls suggests that very possibly water may be carried through them; that indeed their structure may be regarded as a column of water held together by the molecules of the lignified substance. This view is supported by the behaviour of lignin, which while refusing to absorb much liquid and swell, as cellulose does, yet can contain a certain quantity which it will part with very easily. On the other hand compression of the vessels by a vice, if carried so far as partially or entirely to obliterate their cavities, materially interferes with the rate of flow.

Many causes appear to co-operate in maintaining this upward stream. We have the constant pumping action of the cortex of the root, giving us the force known as *root-pressure*. We have also the modified evaporation from the surface of the green parts of the plant, which we have spoken of as *transpiration*. Between these two a third force comes into play, which is necessary to connect the other two. The water forced into the wood vessels by the filtration due to root-pressure is found to saturate them throughout their length. The ultimate ends of the separate vascular bundles in the leaves are surrounded by parenchymatous cells which contain various osmotically active substances. Consequently osmosis takes place between them and the water-containing tracheïds, and the water is withdrawn from the latter. Osmosis seems to be very active in the cells of the leaves, and no doubt plays an important part in conducting the water to the cells abutting more conspicuously upon the intercellular spaces in the parenchyma. Besides these three forces, other factors have been held to co-operate, though much less certainly than they. The walls of the vessels having extremely narrow calibre, capillarity has been suggested as playing a part. This cannot, however, have much effect in a system of closed tracheïds, like those of the secondary wood of the Conifers, which nevertheless conduct the water. It has been thought that the living cells of the parenchyma which abut upon the woody tissue of the stele may play a part similar to the pumping action of the root. Against this theory we have the fact that if the transpiration current be made to contain substances that are poisonous to the living cells, and the latter are consequently killed, the current still goes on. Nor do differences of gaseous pressure within and without the plant, or at different portions of the axis, explain the matter more satisfactorily.

We may now discuss the chief forces in the movement more fully.

Root-pressure.—We have shown how the absorption of water osmotically from the soil by the root-hairs leads to a great turgescence of the tissue of the cortex of the root, which turgescence exerts considerable pressure on the sides of the vessels and tracheïds of the xylem of the stele. By this means water with various salts and other constituents in extremely small quantity, is forced into the fibro-vascular tissue. The process is not a purely physical one of filtration under pressure, but is regulated to some extent by the protoplasm of the most internal cortical cells. When these are distended to their greatest capacity the protoplasm appears to be stimulated, perhaps by the very distension, and in consequence to allow water to transude through its substance. This mode of response to stimulation is not infrequent in vegetable tissues; indeed, it appears to correspond to the response of a muscle to stimulation by the process of contraction. The protoplasm thus relieves itself of the over-distension, and we get an intermittent pumping action set up, which has a certain rhythm. By it large quantities of liquid are continually being forced into the axial stele.

This water, under particular conditions, may accumulate in the vessels, and its presence can then very readily be demonstrated and the force of the root-pressure measured. If a vine stem be cut through in the early spring, before its leaves have unfolded, a continuous escape of water takes place from the cut surface, and the vine is said to *bleed*. This phenomenon is not peculiar to the vine, but is shared in by all other terrestrial plants. In many herbaceous forms this forcing out of water by root-pressure may be seen without cutting the plant at all. Many grasses and other herbaceous plants show in the early morning a certain exudation of water from the tips of their leaves, which is due to the same over-turgescence.

To measure the root-pressure in a plant the apparatus shown in *fig.* 1233 may be used. It consists of a T-piece of glass tubing which is fastened by indiarubber rings to the top of a cut stem, such as that of Helianthus. To the side arm of the tube a bent tube of capillary bore is attached by a tightly fitting cork, and the T-piece is filled with water. Mercury is poured into the bent tube till it stands at a level a little below the cork. As the root continues to take up water it forces it into the tube R, whence it overflows into the capillary tube, causing the mercury in its two limbs to be at unequal levels. By the displacement of the mercury the force of the root-pressure can be estimated.

The root-pressure of various plants has been measured by different observers; an idea of its amount may be gathered from the fact that a medium-sized Fuchsia in a pot has been found able to send a column of water up a tube of the same diameter as its stem to a height of twenty-five feet.

FIG. 1233.

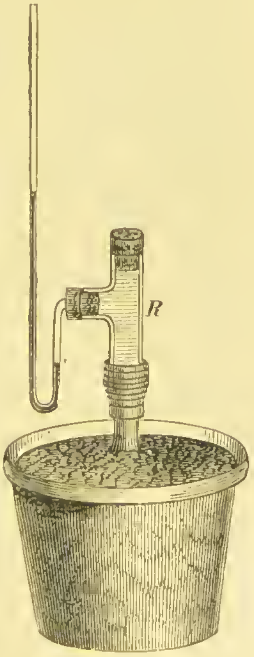


Fig. 1233. Apparatus for the estimation of root-pressure. (After Sachs.)

This force is continually at work while the transmission of water is going on, but it is not easily seen later in the year. If the stem of the vine be cut in July instead of April, no bleeding follows the wound. This is not, however, due to the absence of the activity of the roots, but to the fact that a copious evaporation is taking place from the leaves. In the experiment in April the conditions were different, there were no expanded leaves, and the water absorbed and sent upwards by the root consequently accumulated in the vessels of the stem, escaping at once when the latter was cut; in July the vessels had been emptied by the transpiration, and there was no accumulation of water there to overflow. The apparatus just described will show, however, that the root-pressure is still at work if it be used in July.

The root-pressure, though always considerable, is not constant in amount; it is lowest in the early morning, when it begins to increase; it continues to rise till about midday or a little later, then gradually sinks. A second rise takes place towards evening, and then it falls continuously all night. The causes of this rhythmic daily period are at present unknown; it does not appear to depend upon variations of its surroundings, but to arise from some cause inherent in the constitution of the plant.

TRANSPIRATION.—The modified evaporation taking place from the surfaces of the succulent parts of plants, and regulated in amount by the protoplasm of the cells, is known as transpiration. It is easy to demonstrate the fact of its continuous existence by enclosing a plant, or part of one, in a dry glass vessel, which can be closed so as to admit no air. Very soon the surface of the glass is covered by a fine dew, which is the condensed vapour escaping from the plant. The same thing may be seen if a vigorous plant be covered over by a bell-jar, the water condensing copiously upon the sides of the latter.

The evaporation takes place to a certain extent through all the epidermal cells of the transpiring organ, but not to a very great one, the degree of development of the cuticle having considerable influence upon the amount. It is carried out much more freely through the thin walls of the cells abutting upon the intercellular spaces, which, as we have seen, communicate with the external air by means of the stomata and the lenticels. The transpiration is most copious in the leaf, the structure of the lower side of which, in dorsiventral leaves, is especially favourable to it. If a leaf be taken which has stomata upon its under side only, and the rate of transpiration from its two surfaces be compared, it will be found that the stomatal gives off considerably more vapour than the other surface.

The amount of moisture given off in transpiration varies in different plants. In the Sunflower (*Helianthus*) the amount has been stated to be $\frac{1}{163}$ cubic inch of water per square inch of surface in twelve hours. Doubtless individual plants show a considerable variety, however, in the amount. This copious evaporation readily explains why bleeding of plants from wounds cannot be observed when the leaves are expanded and active.

The removal of the water accumulated by root-pressure in the closed system of vessels leads to a diminution of the pressure of the air they contain, so that while transpiration is active there is a negative gaseous pressure existing in them. This is of considerable importance in assisting in the movements of gases in the plant, and it further helps the pumping action of the root in pressing forward the water by exerting a suction upon the parenchymatous cortex.

Transpiration is not a process of simple evaporation. As in the other phenomena we have examined, the protoplasm exercises a regulating influence upon the escape of watery vapour from the cell. If the amount given off from a measured area of leaf surface be compared with the amount evaporated from an equal area of free water, the latter is found to be much the greater. The difficulty of making a comparison of the area subject to the evaporation is very great, for the escape of watery vapour takes place over all the internal surfaces abutting on the intercellular spaces, which probably measure many times the external area of the leaf, which contains their stomatal openings. The evaporation from the free surface of water is probably many times as great as that from an equal surface of wet cell-wall. That this is due to the life of the leaf, and therefore to the protoplasm, is seen from the fact that a dead leaf gives off its water and dries up more rapidly than a surface of freely exposed water. The cuticle of the living leaf and its cell-walls are consequently not the causes of the differences observed.

FIG. 1234.

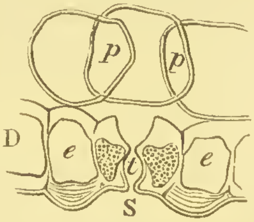


Fig. 1234. Stoma of Hyacinth leaf. *e.* Epidermal cells. *t.* Opening of the stoma. *p.* Parenchyma of the leaf.

If the protoplasm of the cells of the turgid leaves of a branch be stimulated by violently shaking it, the leaves become flaccid. The protoplasm under the stimulus allows more vapour to pass through it, as that of the cortex of the root permitted water to pass out of its cells under the stimulus of over-turgescence.

The ultimate exudation of watery vapour is thus seen to be chiefly carried out through the stomata of the green parts, at any rate in those plants which possess them. The mechanism of the stomata has already been alluded to. The guard-cells which surround the aperture are capable of varying turgescence, the water entering and leaving them from the other cells of the epidermis, which abut upon them. Those walls of the guard-cells, which abut upon the air space underlying them, are, as a rule, thickened and cuticularised (*fig.* 1234), so that vapour cannot enter them. The wall between them and the next epidermal cell is thin and readily allows of osmosis. The guard-cells themselves differ from the rest of the epidermis in the higher plants by containing chloroplasts, which suggests the presence in them of more osmotic substances than the other epidermal cells contain. The guard-cells are so attached to each other that turgescence causes them to separate, opening the aperture. Loss of water induces in them a flaccid condition, and their edges fall together and partly or wholly close the slit. Hence when the cells of the epidermis are turgid, the stomata open; when they lose their turgescence these organs are closed. Thus the escape of watery vapour is accelerated or retarded by their action.

Transpiration is markedly increased by light, rising to many times its original amount when a plant is transported from darkness into sunshine. This is not due to the rise of temperature accompanying the illumination, though the greater warmth may have some influence upon it. The effect of light upon the stomata is to cause them to open; hence they are open during the day and closed during the night. It is probable, however, that this is not directly due to the light. If coloured light be employed, it is found that the rays which influence the opening or closing are those which are absorbed by chlorophyll—a fact which has some significance when it is remembered that the guard-cells contain that pigment.

Other external conditions which have an influence upon this function are the hygrometric condition of the air, the temperature of the soil in which the roots of the plant are embedded, and the mechanical disturbances to which the plant is subjected. If the air be dry, transpiration is vigorous; if moist, then it is checked. If a plant be exposed to a warm dry atmosphere till the leaves droop from too great a loss of water and then be transferred to one saturated with moisture, after a short time they again become turgid. This is not due to an absorption of water in the form of vapour by the leaves, but to a diminished loss by the checking of transpiration. The return of turgidity is caused by the accumulation of the store drawn from the earth by the roots. Warming the soil increases the amount of vapour given off by the leaves. The mechanical disturbance of shaking has already been alluded to, and it has been seen that when thus stimulated, the protoplasm allows transpiration to increase. This helps to explain the flaccid condition observable in some trees after the prevalence of a high wind. The continued renewal of the air around the transpiring organs may also have the effect of increasing the removal of vapour.

When transpiration is excessive, the leaves and branches lose their turgescence, become flaccid and droop. A branch which has reached this condition may be revived by forcing water into it, which can be done by fastening it in one arm of a

U-tube containing water and pouring mercury into the other. The restoration of the water restores the turgidity of the tissues.

Transpiration is of the greatest importance to the plant in many ways. By maintaining a copious flow of liquid to the cells of the leaves, it brings to the metabolic cells of their mesophyll a supply of the materials needed by the plant for the construction of its nutritive substances, and it assists in the transportation of the stored material laid up in various parts of the stem and root to the growing parts and other seats of consumption. Its influence in maintaining the turgidity of the tissues is also very considerable, and this turgescence is of the highest importance to the growing cells, growth itself and many adaptations to changes in the plant's environment being dependent upon it. The negative gaseous pressure in the vessels, already alluded to, is dependent upon transpiration. The importance of the presence of the water to the life of the protoplasm has already been shown.

CHAPTER V.

THE FOOD OF PLANTS. INTRODUCTORY.

A GOOD deal of misconception exists as to the nature of the food of plants. The character of their environment and the absence of any means provided in their structure for taking in material of a nature in any way approaching the composition of living substance, have led to a not unnatural idea that they feed upon simple inorganic compounds of comparatively very great simplicity. The idea has found considerable support in the fact, which is easily ascertained, that such bodies are those which are absorbed in the first instance. By their roots when they live fastened in the soil, or by their general surface when they are inhabitants of water, comparatively simple inorganic salts are found to enter them with the water that they take up. By their green parts, and especially by their leaves, carbon dioxide is absorbed, either from air or water, according to their habit. A study of the whole vegetable kingdom, however, throws considerable doubt upon the theory that these substances are, in the strict sense, to be called their food. Fungi and phanerogamic parasites can make no use of such bodies as carbon dioxide, but draw elaborated products from the bodies of their hosts. Those fungi which are saprophytic, in the same way can only live when furnished with organic compounds of some complexity, which they derive from decaying animal or vegetable matter. We have no reason to suppose that the living substance of these non-chlorophyllaceous plants is so radically different from that of their green relations that it has a totally distinct mode of nutrition.

In the higher plants we find a stage of their life in which the nutritive processes approximate very closely to those of the group last mentioned. When the young sporophyte first begins its independent life—when, that is, it exists in the form of the embryo in the seed—its living substance has no power to utilise the simple inorganic bodies spoken of. The shoot which a potato puts out derives its food from the interior of the tuber. Fleshy roots, corms bulbs, and all bodies which are capable of renewed life after a period of quiescence, show us the same thing; the young shoot emerging from any of them is not fed upon simple inorganic bodies, but upon substances of considerable complexity, which it derives from the tissues of the structure from which it springs.

Even in adult plants of the most considerable complexity we find instances of the same thing; the living substance is nourished by materials which have been constructed by it and stored at various places in its substance till their consumption has been called for.

What, then, are these substances which, in the strict sense, constitute the food of plants? We can ascertain what are necessary by inquiring what are the materials which are deposited in the seed for the nutrition of the embryo when the seed germinates. We find there examples of great classes of food stuffs which are similar to those on which animal protoplasm is supported, and are led again and again to the idea that vegetable protoplasm is essentially identical with the latter. Proteids, carbohydrates, fats, or oils are the materials which, in varied forms, are met with. If we study the protoplasm of a living active vegetable cell and treat it with appropriate solvents, we can extract representatives of these, or of some of them, from its substance, the meshes of which are the places in which it is deposited. The nutrition of the protoplasm can only take place when these substances are brought into the most intimate relations with it; from them, no doubt, in ways not yet discovered, it builds itself up, and by its own decomposition it reproduces them. The interchange of matter between the living substance and its food, the way in which the latter is transformed into the former, are points about which yet almost everything essential remains to be discovered.

But while we recognise that the ultimate nutrition of protoplasm is dependent upon a supply to it of such materials, we are face to face with the fact that such materials are not furnished from the environment to the ordinary green plant. On the other hand we find the latter taking in by ordinary physical processes carbon dioxide from the air and a variety of salts from the soil, and we ascertain that if these are supplied under suitable conditions, the plant can flourish and develop. In one sense, then, these substances constitute its food, but we must carefully consider what we mean by the term. In the nutrition of such plants there are clearly two very different processes concerned, which should be kept carefully distinct. We have the absorption of *food materials* rather than of food in the true sense, and we have, following such absorption, the expenditure of a considerable amount of energy upon these food materials, with the result that they are worked up into the complex compounds which we find protoplasm can assimilate, and which are those which are stored away in the substance of the plant for the nutrition of embryo, bud, or growing point.

This may be made clearer by examining whether these simple inorganic materials are capable of nourishing protoplasm when freely supplied to it. If they are the true food, plants everywhere should be able to make use of them. But if we consider only one of them, the carbon dioxide of the air, we find this is not the case. The plants which are not green, that is, which contain no chloroplasts, can do nothing with this gas. So long as a seed is in the early stages of its germination it is surrounded by carbon dioxide which is given off by its own protoplasm. But it can make no use of it, and if the store of nourishment provided for it in the endosperm or cotyledons is cut off, it inevitably dies of starvation.

If a green plant, which is in good health and endowed with ample vigour, is removed from light to darkness, though carbon dioxide be supplied in appropriate quantity, it can make no use of it.

So with other constituents of the materials from which the true food of the living substance is elaborated. They are absorbed in quantity, but they are not *food* until a considerable amount of work has been done upon them by the plant itself.

In connection with the nutrition of plants we have thus to deal with the absorption of the crude food materials and to study the changes which they undergo after such absorption. But this is not all; the food which is laid up in seeds, tubers, bulbs,

&c., is not deposited there in exactly the condition in which the living substance requires it, so that there remains for us to consider the processes which these materials also undergo for the purpose of feeding the living protoplasm. The first process is one of building up complex bodies from simple materials; the second is comparable with the *digestion* which is so marked a feature of animal alimentation, and is one of breaking down very complex bodies into simpler ones. The nutrition of the protoplasm shows two similar phases; the appropriation of the ultimate constituents of the food, or its *assimilation*, is a constructive process; it is in turn associated with a destructive one, by which, from the protoplasm itself and by its own activity, simpler bodies are produced. The whole round of changes which embraces all these operations is called *metabolism*, the constructive processes being grouped together under the name of *anabolism*, the destructive ones under that of *catabolism*.

The absence of well-differentiated organs set apart for the discharge of these functions makes it rather difficult at first to appreciate their independence. In the animal body such a differentiation is easily seen, but in plants the cellular structure is so prominent, and the life of the protoplasm is so closely related to its condition in the cell, that attention needs to be specially directed to the point. Each protoplast is dependent upon the contents of its own vacuole, and the early constructive processes in the metabolism may take place in it side by side with the digestive ones and at almost the same time. True, a certain division of labour can be noted, but it is not very clearly associated with particular structures. Thus the leaf is especially concerned in the processes of anabolism, but it is mainly so by virtue of the chloroplasts which its cells contain. These processes can go on perfectly well in other parts than leaves; indeed, wherever there are chloroplasts we know they do. Thus, though we associate the leaf with anabolism, it would be wrong to say that it is the organ to which this process is referred. We can say with greater accuracy that the *chloroplast* is the organ conducting these preliminary anabolic processes, and that they take place wherever the chloroplasts are found. Their wide distribution, however, shows us that there is not a specially differentiated member of the plant set apart to be an organ for this function. In the same way, a catabolic process, the digestion of stored products, goes on wherever there are reservoirs of such bodies, and there, and there only, unorganised ferments or enzymes are found, instead of being located in particular glands, as in the animal body. These reservoirs, we have already seen, and shall see again later, are found in the most varied regions of the plant's substance—regions, moreover, which vary considerably in different plants.

Starting, then, with the intricacy of the metabolic processes placed before us, and with their relations to each other, we may begin the consideration of them in detail with an inquiry into the introductory absorption of the materials from which the food is ultimately made. Even here we meet with some complexity, as the ordinary green plant shows marked differences in behaviour from its parasitic relation, and from the great class of fungi, which possess no chlorophyll. It will be best to consider first the ordinary terrestrial green plant, noticing in passing differences in behaviour shown by aquatic and epiphytic forms.

CHAPTER VI.

THE ABSORPTION OF FOOD MATERIALS BY A GREEN PLANT.

We have seen that the materials which protoplasm is eventually able to assimilate, and which, therefore, constitute its food, are of a similar nature to those deposited in seeds and other storehouses of nutriment which are variously disposed in its substance. We know, further, that these are not the materials which an ordinary green plant takes into itself from the environment in which it lives. On the contrary, we know that its structure prevents its taking in anything solid, but that it is continually absorbing liquid by means of its roots. Between the raw materials that can be so absorbed and the complex products which are needful for the nutrition of its substance there is a great difference, and the manufacture of these latter from the raw materials taken in constitutes a very important part of the metabolic processes.

To ascertain what this work of contruction consists of, we must find out what elements the substance of the plant and the true nutritive matter contain, how these are supplied to the plant, and what work is done upon them in its cells.

As already noticed, the structure of the plant demands that all the materials of a solid character shall be in such a form of solution that they can enter its substance by means of the physical process of osmosis, modified as we have described. This is equally true of gases, of which there is considerable absorption by all plants, whatever be the nature of their habitat.

The details of absorption vary to some extent, however, according to the environment of the plant. Aquatic plants can absorb water and whatever is dissolved in it, whether of gaseous or solid character, by all parts of their surface. Those which grow with their roots embedded in soil and their shoots exposed to the air show a certain division of labour in this respect. The mineral constituents obtained from the soil are taken in by the roots with the stream of water; those of a gaseous nature mainly find entry through the leaves and other green parts.

If we examine the food stuffs described as being essential, we find that proteids contain carbon, hydrogen, oxygen, nitrogen, sulphur, and perhaps phosphorus. Carbohydrates and fats contain only the first three of these elements. A destructive analysis of the plant, made by burning it, shows that it contains others also; for after all the volatile products of combustion have been driven off, a certain inorganic residue is left, which is composed of several metals and some other elements. An analysis of this residue, which is spoken of as the *ash*, will not, however, tell us in what condition these different constituents exist in the living plant, on account of the various chemical changes which go on during the combustion.

The ash of plants is found, when analysed, to contain always the four metals—potassium, magnesium, calcium, and iron. These are not present in the metallic condition, but in combination with various acids, forming nitrates, sulphates, chlorides, carbonates, phosphates, &c.

Besides these, various plants may individually contain greater or less quantities of many other elements variously combined. We find sodium very generally present; less frequently so aluminium, copper, zinc, manganese, silicon, bromine, iodine, and others. Indeed, the composition of the soil in which a plant grows determines to a very great extent what minerals enter it. If a substance is soluble in the liquid which the root-hairs absorb, a certain quantity will, by ordinary physical processes, be taken up by them.

The quantity of each substance a given plant will absorb will depend upon whether the plant makes use of it in any way. If so, it will be quickly removed from the absorbing cell and more will enter. If not, the cell-sap of the absorbing root-hair will soon have taken up as much of it as it can contain, and the absorption of that particular substance will cease.

Some of the materials found in the soil are readily soluble in the water which the soil contains. Such can enter the plant without difficulty. Others are soluble only in water containing carbon dioxide, and as considerable quantities of this gas are continually being generated in the soil, the water there is charged with it, and bodies, otherwise intractable, are thereby brought into solution and absorbed. A third factor in the process of absorption is the acid sap which the root-hairs contain. Not only does this acid cause water to enter osmotically, but a little of it exudes in the same way, and this has a certain solvent action upon the particles to which the root-hairs cling. Thus certain salts can be absorbed, though soluble neither in pure water nor in water containing carbon dioxide.

The solutions taken in are excessively dilute. There is, however, a certain relation necessary between the substance and the water, for we have already noticed that strong solutions cannot pass the lining layer of protoplasm. Every salt is taken up in a certain strength of solution, or, in other words, with each molecule of salt there is a certain invariable quantity of water absorbed. The quantity is not the same, however, for each salt.

The salts which different plants absorb, in like manner vary as to amount. If two different species are growing in the same soil, side by side, under exactly the same conditions, the amounts of the several salts present in the soil which are absorbed by the two plants will not be the same. In each case the quantity will vary according to the use which the plant can make of it.

Conversely, if the same soil contains several different salts, a plant will not absorb them in equal proportions, nor in those in which they exist in the soil. This fact admits of a similar explanation. Again, the absorption of a salt will cease as soon as the cell-sap contains the same amount of it as the fluid outside the root-hair. In this case there will be no osmotic action so far as the salt is concerned, though there may be a continuous amount of water entering the hair.

We have seen that the continuous absorption of water by the root-hair will depend upon certain external conditions, such as the temperature of the soil, the activity of transpiration at the time, &c. These conditions affect also the absorption of the substances in solution.

The substances which are absorbed in this way by the roots are naturally very varied. The most important of them in the metabolism of the plant are the compounds of nitrogen. In the soil these exist in the form of nitrates or nitrites of the metals mentioned, and as compounds of ammonia. Green plants take in little or none of the latter, which are, however, made available for their use by the action of certain bacteria which the soil contains, which have the power of converting the ammonia compounds into nitrites and the latter into nitrates, in which form they are taken up. This process of *nitrification* is the special property of two of these organisms, one of which forms nitrites from the ammonia compound, and the other forms nitrates from nitrites.

It is in this way that a normal green plant absorbs all the nitrogen which it uses for the construction of food substances. The nitrogen of the air is made use only of in very exceptional cases. Certain lowly Algæ seem to have the power of using it, but the process is not fully understood. A few plants belonging to the Leguminosæ can also use atmospheric nitrogen, but their power depends upon the association with their roots of certain fungi which infest the cortical tissues and develop peculiar tubercular structures upon the roots. The actual mode of absorption in this case also is obscure; the parts played by the root and the fungus respectively are not at all determined.

The water taken up is the main source of the hydrogen and oxygen which are used in the anabolic processes. A little of both these gases is taken in in the several combinations of the metals; sulphates and phosphates contain both, nitrates and carbonates contain oxygen. The amount of them absorbed in these forms is, however, relatively small. The other elements mentioned enter the plant in various combinations in the water stream.

The gases in solution in the water of the soil also make their way into the root-hairs with the stream, but the quantity is small compared with what is absorbed by the aerial parts. The gas carbon dioxide which we have seen to be present in the earth in considerable amount, is, however, not made use of in the anabolic processes. All of this particular food material is taken in from the air. A little carbon is absorbed in the form of carbonates. More complex organic compounds of carbon are taken in by those roots with which fungi are living symbiotically, such as the mycorhiza of some trees, but this is exceptional.

The absorption of gases from the air takes place in the leaves and other green parts. They enter freely through the stomata and find their way thus into the intercellular spaces, which are very numerous. These intercellular spaces contain a mixture of gases which, though approximating to the composition of atmospheric air, yet differs from it in the relative quantities of the constituents. This can be readily understood from the consideration that considerable gaseous interchange goes on in these spaces between the air they contain and the living cells which abut upon the spaces. The cell-walls here are very delicate and thin, and are saturated with water. In this water the different gases present dissolve according to their degree of solubility. The quantity of each taken up depends, as in the case of the metallic salts just discussed, upon the ability of the cells to make use of the gas. If it can be combined in any way with other bodies in the cell, it is withdrawn thus from the sap and room made for more to enter. If not, the limit of saturation of the sap is soon reached.

Probably little or no absorption of gas takes place through the cells of the epidermis. though they are freely in contact with the air. Sections show us that they are provided usually with a cuticle, which resists any such solution as is necessary for absorption.

The only gas which is absorbed as a food material from the air is carbon dioxide, CO_2. This exists to a very slight extent in the atmosphere, only about four parts in ten thousand being normally present. The very large green surface which an ordinary terrestrial plant possesses renders, however, a considerable amount of absorption possible. If the general conditions are favourable, the absorption is continuous, for carbon dioxide is at once decomposed in the cells of the green tissue, and so a stream is always entering.

Both nitrogen and oxygen are soluble in water, though to a different extent. It has been already stated that the nitrogen so taken in is not used in the constructive processes, and accordingly but little is absorbed in this way. The oxygen which enters is larger in amount; experiments have proved, however, that it is not a food material, but is used for other purposes.

The absorption of carbon dioxide takes place usually at the ordinary atmospheric pressure or at one a little greater. Plants can, however, absorb this gas when it is present in much larger proportion than it is in air. Too much is, however, possible, and then the cells are unable to take it in at all. The absorption of carbon dioxide is possible only under certain conditions; the cells which contain chloroplasts are the only ones which can take it in in any quantity, and they only when they are exposed to sunlight, preferably a bright light, and when the plant is maintained at an appropriate temperature. Its absorption is accompanied by the exhalation of a volume of oxygen, which is equal to the volume of carbon dioxide absorbed, and it is attended by a continuous increase in the weight of the plant.

We have seen that the water absorbed by the roots is transported regularly through the axis of the plant until it reaches the leaves, in which after traversing the cells of the mesophyll it is evaporated into the intercellular spaces. Into these cells of the interior of the leaf all the food materials are thus at once transported, both those entering from the soil and those absorbed from the air. These mesophyll cells have generally a different arrangement on the two sides of the leaf, but they all agree in containing chloroplasts. In these cells takes place the work of construction of organic substance, such as the plant can live upon, work which is carried out mainly through the instrumentality of the chloroplasts.

As already noticed, various elements are constantly found in plants which do not enter into the composition of the actual nutritive substances. The part that many of them play is obscure; indeed some of them, as sodium, seem to be quite useless. Some play a secondary part in protecting the plant tissues in various ways from destructive influences, some enter possibly only as the medium by which the combined nitrogen, sulphur, and phosphorus are absorbed. Others, especially potassium, calcium, magnesium, and iron, have a part to play in enabling the more important elements to be worked up into nutritive material.

In the cases of some green plants these processes of absorption are supplemented by others. In several Natural Orders there are species which are semi-parasitic in their mode of life. Though they possess leaves, stems, and roots, they do not live entirely at their own expense, but certain of their roots penetrate the tissues of the roots of other plants near which they grow. The degree of this *root-parasitism* varies a good deal in the different groups. These plants supplement the processes we have just described by drawing elaborated food material from the host which they have attacked.

The pitcher plants, *Nepenthes*, *Sarracenia*, &c., and the fly-catching plants, *Drosera*, *Dionæa*, and others, can also absorb nitrogenous material by the special mechanisms which they possess. In the pitchers of Nepenthes, &c., there is an accumulation of water in which insects are from time to time drowned. Their bodies decay or are digested, and the products of the decomposition are absorbed by the tissue of the pitchers. The flies and other insects captured by Drosera and its allies are similarly disposed of.

CHAPTER VII.

THE CHLOROPLASTS AND THEIR FUNCTION.

We have seen that the different materials out of which the food of the plant is constructed are carried by various means to the cells of the parenchyma of the mesophyll in which chloroplasts are present. The chloroplast is a small differentiated body consisting of protoplasm in the meshes of whose substance a green colouring matter, *chlorophyll*, is contained in some form of solution. Alcohol, chloroform, ether, benzol, and other liquids can dissolve the chlorophyll and leave the plastid colourless. Chlorophyll is not soluble in water, nor can it be extracted with acids or alkalies without alteration.

A solution of chlorophyll in any of the liquids mentioned shows the curious property of *fluorescence*; if regarded by transmitted light it appears green, but if a strong solution is looked at by reflected light it has a blood-red coloration.

If a solution of chlorophyll is placed in the path of a beam of light which is then allowed to fall upon a prism, the resulting spectrum is found to be modified. Instead of showing a continuous band in which all the colours are represented, it is interrupted by seven vertical dark spaces. The rays which in the absence of the solution of chlorophyll would have occupied those spaces have no power to pass through it, or, in other words, chlorophyll absorbs those particular rays of light which are missing.

In *fig.* 1235 is a representation of the spectrum, called from the facts just narrated the *absorption* spectrum. The first band on the left is the darkest, and is found to be in the red part of the spectrum. The three bands on the right are broader, but not so well defined. They cover nearly all the blue end. The three thinner and lighter bands are in the green and yellow parts of the spectrum. Chlorophyll therefore has the power of absorbing a large amount of red rays, a good many blue and violet ones, and a few of the green and yellow. The distinctness with which the absorption bands are seen will depend upon the strength of the solution, the red and blue being, however, always prominent.

Careful chemical experiments have proved that chlorophyll is a single pigment, and not a mixture of two as has often been stated. It is, however, very easily decomposed, and the products of its decomposition are generally found with it in the chloroplastid. One of these, *Xanthophyll*, which is of a bright yellow colour, is always extracted with the chlorophyll by alcohol. It can be separated by appropriate treatment.

Chlorophyll is formed in the chloroplasts only when they are exposed to light, except in one or two rare cases. When a plant is grown from a seed or a tuber in the dark, the resulting stem and leaves are not green, but of a peculiar yellowish-white appearance. Nor can it be developed in the absence of a suitable temperature. Its formation has been found to depend upon the presence of iron in the plant, but the exact relation of the iron to the pigment is not known; it does not appear to enter into the composition of the latter.

Fig. 1235.

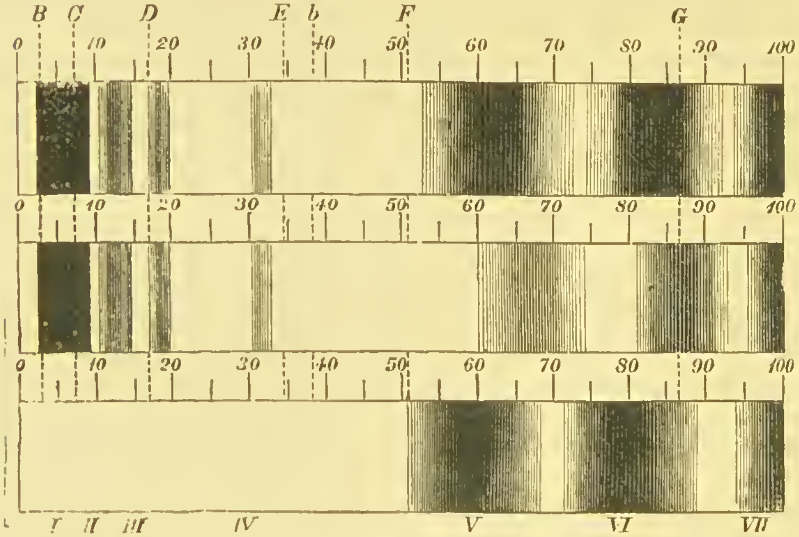


Fig. 1235. Absorption spectra of chlorophyll and xanthophyll. (After Kraus.) The upper spectrum is given by an alcoholic extract of leaves, the middle one by dissolving chlorophyll in benzol, and the lowest by xanthophyll. The bands in the least refrangible portion, B–E, are figured as obtained with a concentrated solution; those in the most refrangible part of the spectrum, F–G, are given as obtained with a weak solution. The letters B–G indicate the principal rays, the numbers I–VII the absorption bands of chlorophyll from red to violet, and the figures 0–100 divide the length of the spectrum into 100 equal parts. (After Sachs.)

The construction of organic substance proceeds in the cells of the mesophyll containing the chloroplasts and supplied with the raw materials in the way described in the last chapter. The complex products of the anabolic process are at first mainly, if not entirely, confined to two classes, carbohydrates, and some nitrogen-containing compound, probably proteid. Many other forms of organic substance appear in plants, such as fats or oils, glucosides, &c., but these are probably all produced by processes of catabolism, and are not directly constructed from the simple bodies absorbed.

We will examine first the process of formation of carbohydrates. These consist of the elements carbon, hydrogen, and oxygen, the latter two existing in the combination in the same proportion as they do in water. The source of the carbon and the oxygen is the carbon dioxide absorbed from the air, while the hydrogen is derived from the water of the cell-sap. The process can only take place under the influence of light and while the cells are at an adequate temperature. It has generally been spoken of as the assimilation of carbon dioxide; but there are objections to this term, as the word *assimilation* is often used to indicate something entirely different, viz. the actual appropriation of prepared food stuffs by the living substance. As the process under consideration is one of building up complex substances from very simple ones, and takes place only under the influence of light, it has recently been termed *photosynthesis*.

When carbon dioxide is exposed to the influence of the chloroplast in the presence of light and moderate warmth, it is thought to undergo a decomposition which may be expressed by the equation $2CO_2 = 2CO + O_2$, splitting up into carbon monoxide and oxygen. At the same time, water is decomposed, probably in the way denoted by the equation $2H_2O = 2H_2 + O_2$. The two molecules of oxygen unite and are exhaled, the quantity being the same as the quantity of carbon dioxide undergoing decomposition. The two residues, $2CO$ and $2H_2$, are then thought to unite to form $2CH_2O$, a body known as formic aldehyde. It is a property of the aldehydes to undergo readily what is known as *polymerisation* or condensation of several molecules together. Such a condensation of formic aldehyde would lead to the formation of sugar thus,—$6CH_2O = C_6H_{12}O_6$; and it is suggested that this process takes place. At any rate, sugar is present in the mesophyll cells very speedily after the absorption of the carbon dioxide and the beginning of the exhalation of oxygen.

These processes are carried out by the chloroplast under the conditions set forth. It is evident that such changes as the decomposition of carbon dioxide and water cannot be accomplished without a good deal of energy being expended upon them. In this need we have the explanation of the composite nature of the plastid. The chlorophyll absorbs certain of the rays of light that fall upon it, and the energy so acquired is applied by the protoplasm of the plastid to effect the decompositions that take place. Sugar is the result, though what kind of sugar is first formed is still open to experiment. There is a fairly copious and continuous production of it, indicating, as in the case of the raw materials and the cells which absorb them, that there must be a removal of it as it is formed. Otherwise the cell-sap would soon be saturated with sugar and its formation would cease. The quantity which is in excess of the immediate needs of the cell may either be transported away from it by diffusion, or some of it may be converted into an insoluble form and be temporarily deposited in the cell. The latter operation is carried out by the plastid, which quickly forms small granules of starch in its own substance, at the expense of some of this surplus sugar. The starch can readily be detected *in situ* by treating the leaf with iodine, after bleaching it by soaking it in alcohol. This formation of starch was formerly held to be the last stage in the ordinary anabolic processes; but as starch must be re-converted into sugar before protoplasm can use it as food, its occurrence is now held to be a case of what we shall see is a very usual thing in plants, the accumulation of food material in various parts, to be there held in reserve till the plant requires them.

It is not certain that the process of construction of carbohydrate is so simple as what has been said would imply. There are many other chemical compounds in the cell while it is proceeding, and to what extent they take part in the matter is not known. It is held that some compound of potassium, at any rate, is concerned in the process, for in the absence of this metal sugar does not appear to be formed.

The formation of the proteid bodies in the cells is not at all well understood; indeed, but little is known certainly about it. The nitrates are absorbed and taken to the mesophyll cells. In these cells and in others about the plant, bodies occur of comparatively simple composition, though much more complex than nitrates. These, which are known as *amido-acids*, include asparagin, leucin, and several others. Probably they are intermediate bodies constructed from the nitrates, though in many cases they arise from the decomposition of proteid and not from anabolic processes. It is in the form of these bodies generally that organic nitrogenous matter travels about the plant. From them most likely proteid is constructed, compounds of sulphur and of phosphorus in the cells supplying those elements, which, as we have seen, are probably both in the molecule of proteid. Certainly sulphur enters into its composition.

Again there is reason to think that the carbohydrate manufacture is associated with the nitrogenous one. Proteid can apparently only be formed by green plants under the same conditions as carbohydrate, though we cannot say that chlorophyll is directly concerned. If a shoot is not exposed to light, there will be an accumulation of asparagin in its tissues; the same thing will be observed if carbon dioxide is excluded from access to it. Indeed, if photosynthesis is prevented, proteid material cannot be formed.

The proteids, if formed in the leaves, as is probably the case, are affected just as we have seen the carbohydrates to be. They undergo a partial decomposition, and their nitrogenous residues leave the cells in the form of amido-acids. Their further fate will be examined later.

The proteid, which is the most complex body known to exist in the plant with the exception of the living substance itself, cannot at present be represented by any chemical formula. Analyses of the purest forms of it point to its percentage composition lying within the following limits:—

Carbon	50·0	to	55·0
Oxygen	22·8	,,	24·1
Nitrogen	15·0	,,	18·2
Hydrogen	6·8	,,	7·3
Sulphur	0·4	,,	0·5

There are several classes of these bodies known, the differences which they show depending chiefly on their solubilities in different liquids. The best known groups are the following:—

1. Albumins. These are soluble in distilled water, and if the solution be heated the proteid is converted into a peculiarly insoluble form, known as *coagulated* proteid, and deposited. Albumins can be precipitated unchanged by saturating their solutions with sodio-magnesic sulphate. Their coagulation temperature ranges from 70° to 80° C. They are not of common occurrence in plants, but may be extracted from certain roots.

2. Globulins. These differ from albumins in not being soluble in distilled water. They can be dissolved by adding a little neutral salt, such as sodium chloride. Their solutions are coagulated on heating, and they can be precipitated by saturating them with magnesic sulphate. There are many members of this class, which differ from each other by varying solubility in different strengths of the salt solution. Their coagulation temperatures vary a good deal, some being changed at about 55° C. and others not till about 75° to 80° C.

   The proteids found in plants chiefly belong to this group. They can readily be extracted from most seeds. Probably this form is the one which occurs in the mesophyll cells.
3. Albuminates, or derived albumins. These are soluble in weak acids and alkalies, but their solutions do not coagulate on boiling. They can be precipitated by carefully neutralising the solution.
4. Albumoses. These are soluble in water, and do not coagulate on heating. Their characteristic reaction is that they give with nitric acid a precipitate which dissolves on warming the liquid, and reappears as it cools.
5. Peptones. These are much like albumoses, but do not give a precipitate with nitric acid.

The members of the last two groups are capable of dialysing through membranes, which those of the first three cannot do. The peptones dialyse with far greater ease than the albumoses. They do not occur very plentifully in plants, and are probably formed in them only from the decomposition of the more stable forms of globulin and albumin. Some of the albumoses occur in certain seeds in association with some of the globulins.

By the action of peculiar secretions of the protoplasm, belonging to the bodies known as *enzymes* or *unorganised ferments*, the globulins and albumins can be decomposed, with formation successively of albumoses, peptones, and amido-acids, such as asparagin and leucin.

It has been considered by some botanists that the sieve-tubes or their companion cells are the places where the construction of proteid is completed, only the amido-acids being formed in the leaves. It is, however, possible that this construction is, like that of the deposition of starch in the chloroplast, rather the expression of a temporary deposit of proteid in those cells at the expense of the surplus formation, which, not being needed by the cells of the mesophyll, is converted into amido-acids and so transported from the leaf. A certain amount of proteid can be extracted from the living cells which are the seat of the original anabolic processes.

The formation of proteids can be carried out by fungi, though the latter cannot construct carbohydrates. Indeed, they can commence the synthesis at a lower stage than the green plants, beginning the construction with compounds of ammonia, which have to be converted into nitrates before green plants can utilise them.

The importance of the inorganic salts which do not enter into the composition of the living plant-substance is very imperfectly understood. Potassium is apparently necessary for the construction of carbohydrate matter by the chloroplastids. It is generally absorbed in combination with sulphuric, nitric, and hydrochloric acids, and can be found in the plant in combination with organic acids such as tartaric, oxalic, and malic. It usually occurs in quantity in places where starch and sugar are stored.

Calcium and magnesium are absorbed in similar combinations, but their function has not been ascertained. The former appears to be concerned in the transport of carbohydrates from place to place. Both are of service in neutralising such acids as oxalic, the presence of which in quantity is deleterious. We frequently find in cells, and in some cell-walls, crystals of oxalate of calcium.

The importance of iron has been pointed out in connection with the action of the chlorophyll.

Most of the other elements absorbed seem to be without effect on the metabolic processes.

CHAPTER VIII.

RESERVE MATERIALS, AND THEIR DEPOSITION.

We have seen that the amount of food constructed in the mesophyll cells from the crude materials absorbed is often considerably in excess of their immediate need. A certain amount is, no doubt, used up at once by the living substance of each cell, the assimilation of the food being the culmination of the anabolic processes, as protoplasm is the most complex material existing in the plant. The remainder is otherwise disposed of;

no doubt a certain quantity is always retained in the cell to supply the needs of the protoplasm when actual construction is intermitted. Evidence of the temporary accumulation of a local reserve store is afforded by the occurrence of the starch-grains which the chloroplast forms inside its own substance. A great deal of the manufactured organic matter is, however, constantly leaving the cells in which it is formed, and passing to other parts of the plant. Even the temporary accumulation of starch soon disappears; if a plant, which has been vigorously forming it in its chloroplasts during a summer's day, so that at evening there is a great amount deposited there, is examined early next morning, the leaves are found to be devoid of starch. This is not brought about by its having been used during the night, for if the path of removal is obliterated, as it may be by severing the petiole, the leaf is found as full as on the previous evening.

Evidently, then, the surplus food manufactured in the mesophyll is transferred from the seat of its elaboration to other parts of the plant. To bring about this removal of the starch and inferentially that of the proteids, a certain alteration of them must be effected, the mechanism of which will be discussed later. The starch is converted again into sugar, and possibly some of the sugar may be further changed, though, no doubt, sugar is the general form of the travelling carbohydrate. The sugar which has not been transformed into starch may travel as it is, or some modification of it, still a sugar, though of another description, may be formed. That sugar is readily removed from the leaf may be inferred from several considerations. We can find but little of it in the mesophyll of the leaf, though we know it is constantly being produced. We do find it, however, fairly easily in the bast of the fibro-vascular bundles of the leaf, and if a leaf is cut off from the stem while construction is going on, it can very soon be detected in the mesophyll cells as well.

Proteids are probably gradually broken down into amido-acids, such as asparagin, which, being a readily diffusible body, can pass through the cell-walls.

These elaborated materials, in their passage from the leaves, travel by the bast and not by the wood. The carbohydrates and the amido-acids probably go by the parenchyma. The sieve-tubes differ from the latter in containing a quantity of proteid material, and it is at least possible that proteid as such may travel by them. If so, it is probably reconstructed in the sieve-tube from the amido-acids, &c., which are being transported from the mesophyll. A certain amount of carbohydrate also may go this way.

That the stream of elaborated food is transported by tissues external to the wood appears clear from the fact that if an incision be made round a branch or trunk of a tree and a small ring be removed, extending inwards as far as the wood, the growing parts below the wound dwindle and die, while those which leave the axis above the incision become more luxuriant.

Even along the path of the stream we find the same tendency to temporary deposition which we noticed in the chloroplasts. When the progress of the stream is checked from any cause, we find a temporary accumulation of starch near the point of stoppage, which disappears when the flow again asserts itself.

The direction which the food substances take is dependent upon many circumstances. When growth is active in any part, whether an apical meristem or a cambium layer, the stream is directed towards such seat of consumption. This is due to a process of diffusion set up in consequence of the removal of constructive material from the stream by the growing cells, and the consequent weakening of the solution there. When there is more produced than is sufficient to supply an immediate demand, the surplus is deposited in some part or other of the plant, to supply future needs. There is thus continually going on during active life a storage of surplus food substances in places which we may call reservoirs of reserve materials. In some cases they are again very speedily removed, but in others they remain there for a considerable time.

The nature of these reservoirs is very varied. Seeds, tubers, bulbs, corms, fleshy roots, and other similar structures are perhaps the most easily examined. In seeds the reserve materials are deposited for the support of the young embryo, which will need them at the onset of germination. Tubers will require them for the support of the young shoots to which they give rise. Fleshy roots have to support a vigorous outgrowth after the expiration of winter. In the axes of woody plants we find stores laid up in sheaths of cells, such as the endodermis or pericycle, or in the medullary rays existing in the secondary wood.

In these reservoirs the stored substances are deposited in an insoluble form, or at any rate in a shape which is not suitable for rapid transport. In most plants the reserve carbohydrates are stored in the form of starch-grains, which generally differ from those in the chloroplasts by their larger size and apparent complexity of composition. They are formed at the expense of the sugar of transport, usually by special bodies known as *leucoplasts* from their white colour. These bodies are very much like chloroplasts, except that they contain no chlorophyll. The leucoplast appears to absorb the sugar and pour out starch from some part of its surface. Layer after layer is so excreted, till a recognisable starch-grain is produced, which shows the manner of its growth by faint striation of its surface, the striæ showing the limits of the successive lamellæ laid down. In some cases the lamellæ are strictly concentric; in others, as in the potato, the end next the leucoplast gradually becomes broader and broader, so that the shape somewhat resembles that of an oyster-shell. *Fig.* 1236 shows a group of leucoplasts actively forming starch-grains. *Fig.* 1237 shows the striations of the complete grain.

FIG. 1236.

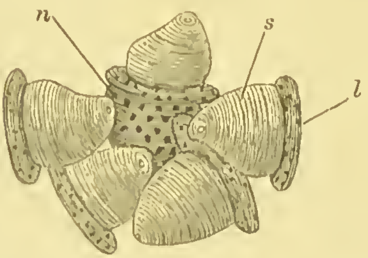


FIG. 1237.

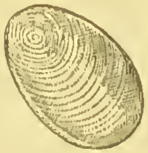


FIG. 1238.

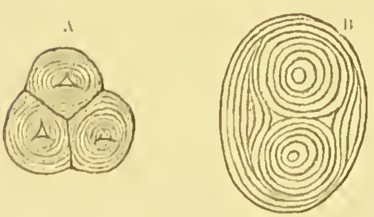


Fig. 1236. Group of rod-like leucoplastids, *l*, each bearing a starch-grain, *s*, collected round the nucleus, *n*, of a cell of the pseudo-bulb of an Orchid (*Phajus grandifolius*). × 500. (After Schimper.)——*Fig.* 1237. Potato-starch (× 250).——*Fig.* 1238. A. Compound: B. Semi-compound granule of starch.

Some grains often found in the potato are not so simple in their structure. These are represented in *figs.* 1238 A and B. The former usually arise by two or more originating in the interior of the leucoplast; as they grow they become closely pressed together and constitute a compound grain. *Fig.* 1238 B shows what is often called a semi-compound grain. In such a formation the leucoplast produces two grains on opposite sides, and as they increase they come into contact. The leucoplast is so reduced to a ring surrounding them at their point of union, and its continued activity then forms new layers surrounding the whole. The leucoplast is gradually used up in its activity and disappears, leaving the grains of starch free. Many variations of its behaviour have been noticed in different cases.

Besides this formation of large starch-grains by leucoplasts we have many cases in which the deposition of starch is effected by the protoplasm of the cell. Such grains are generally very small, and show no structure. Instances of their occurrence have been already given. They are commonly seen in the interior of the plant in reservoirs which are only temporary.

Carbohydrate materials are deposited in other forms in many plants. The root of the beet (*Beta vulgaris*) contains large quantities of cane sugar, as do the stems of the sugar-cane. The bulb-leaves of the onion abound in grape sugar. Many fruits contain different kinds of sugar. Inulin is stored in the tubers and tuberous or fleshy roots of many of the *Compositæ*. Glycogen occurs in the hyphæ of many of the Fungi. In many Palms the carbohydrate is stored in the shape of cellulose, the walls of the endosperm of the seeds being enormously thickened. The cellulose is here formed by the protoplasm of the cells, in the same way as is that which constitutes the thickening layers of the cell-walls of the vegetative part of the plant.

The mechanism of the storage of sugar is not accurately known, but we may argue from analogy that it is brought about by the living substance of the cells, by which also, though diffusible, it is no doubt retained within them.

Proteids are stored similarly; in the meshes of the protoplasm of all cells there is a certain accumulation in amorphous form. In many seeds they are deposited in the form of grains of complex nature, and sometimes of elaborate structure. Grains of proteid material are known as *aleurone* grains. Sometimes they are small, rounded and structureless, as in the Pea (*fig.* 1239). In other seeds, as in the Castor-oil plant, they are much larger, of rounded or ovoid form, and contain a crystal of proteid matter, which often occupies nearly their whole substance (*fig.* 1240). This has been called a *crystalloid*. There is in such cases also a small aggregation of mineral matter which lies close to the crystal. This is known as a *globoid*, and consists of a double phosphate of calcium and magnesium.

The proteids of the aleurone grain are generally mixtures of globulins and albumoses, the latter being least in quantity. If a section of a castor-oil seed from which the oil has been removed, be irrigated with water, a part of the outer substance of the grain is dissolved, leaving still an ovoid body, in which the crystal, or crystalloid, can be seen. The part dissolved consists of the albumose, which is soluble in water. If the section be then irrigated with a 10 per cent. solution of common salt, the body of the grain dissolves. This is composed of a particular globulin. The crystalloid will dissolve if it be treated with a saturated solution of the same salt, showing it to be made up of another globulin.

FIG. 1239.

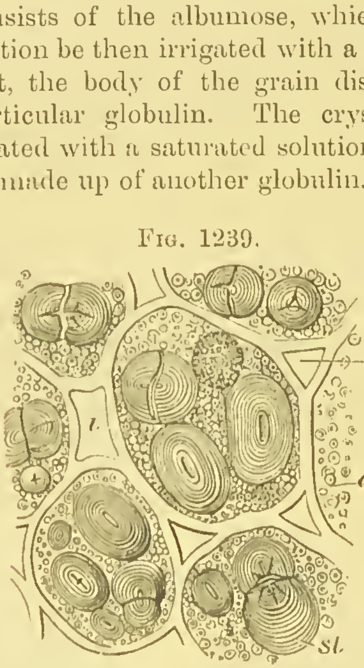


FIG. 1240.

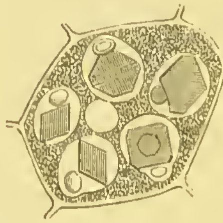


Fig. 1239. Cells of a very thin section through a cotyledon of the embryo in a ripe seed of the common Pea (*Pisum sativum*). *a, a.* Aleurone grains. *st.* Starch granules. *i, i.* Intercellular spaces. (After Sachs.)——*Fig.* 1240. Cell from the endosperm or albumen of the seed of the Castor-oil plant (*Ricinus communis*) in dilute glycerine, showing large transparent proteid or aleurone grains, with crystalloids and globoids embedded in them. (After Sachs.)

Other aleurone grains show other peculiarities of solubility, but probably no other kind of proteid is usually present. Some, however, are thought to be composed of albuminates, as they dissolve only in potassic or sodic hydrate, or other alkalies.

The aleurone grains are frequently associated in the cells of the seed with either starch or oil. Occasionally both these compounds are present.

In other cases the reserves of proteid are crystalline in structure. Crystals of this character are easily found in the tuber of the potato, lying in the cells very near the epidermis. They are also met with in the thallus of certain seaweeds.

Many of them can be made to crystallise from the solvents which are used to extract them.

The mode of formation of these aleurone grains is still not certainly known. Some authors regard them as deposited by a process something like crystallisation following the abstraction of water from the cell. Others have described their formation as one of secretion by the protoplasm. The latter view seems the more probable one.

Fats or oils occur copiously in certain seeds, such as those of the Castor-oil plant (*Ricinus communis*), the Brazil-nut (*Bertholletia excelsa*) and others. They are found also in the cells of the floral leaves of many plants, and in many fruits. They are probably formed by the protoplasm, originating in small droplets in its meshes, which as the fat accumulates run together, till the cell is saturated with it. In some plants certain plastids have been described as forming oil, much as the leucoplasts do the starch-grains. These bodies have been called *elaioplasts*.

Other reserve materials are known which are not so widespread as those already described. Such are the *glucosides* found in many of the Rosaceæ, the Cruciferæ, and allied orders. These are bodies which when decomposed give rise to a sugar, and various other bodies usually belonging to the so-called aromatic compounds. Amygdalin, found in the Cherry Laurel (*Prunus Laurocerasus*), may be mentioned as an example. When split up by chemical means, it gives rise to sugar, benzoic aldehyde, and hydrocyanic acid.

All these bodies, when acted upon by a process analogous to the digestion known in the animal kingdom, are converted into materials which can directly nourish the living substance, or can be transported easily about the plant in a condition of which the latter can readily take advantage, needing indeed very little constructive change to fit it for actual assimilation.

CHAPTER IX.

DIGESTION OF RESERVE MATERIALS.

We have noticed in following the deposition of reserve materials that their permanent form differs from that which they assume for purposes of transport. They are generally insoluble, and almost always indiffusible, whereas they travel in the form of soluble, diffusible bodies. The removal of them from the seats of storage takes place at times dependent on the resumption of activity of growth or development; and as this removal is dependent upon the same methods of transport, they must undergo a process which, from analogy with similar processes in the animal body, may be described as *digestion*. They must, after such treatment, be presented to the protoplasm of the growing cells in much the same form or condition as that in which they were first constructed from the simple bodies absorbed.

There is no special region in the plant where digestion takes place. It may be looked for in any cell in which any form of reserve material is deposited.

We have seen again that in a few rare cases nitrogenous material is absorbed into the plant body through certain leaves or modified foliar organs. The insectivorous plants are materially assisted in their growth by capturing and digesting various insects. *Drosera* does this by means of its sticky leaves, which are furnished with peculiar outgrowths, which bend over and imprison any small insect which alights upon them. The leaf is covered with a sticky or glutinous secretion, which is poured out from these so-called tentacles, and the insect becomes entangled therein. The tentacles then close over the insect and emit a fluid which has the property of digesting the dead bodies so imprisoned, rendering the nitrogenous matters capable of absorption by the leaf tissue. *Dionaea* imprisons any insect visitors by a different mechanism, and digests them by a similar secretion. Many other plants have the same power. Some plants, such as *Nepenthes* and *Sarracenia*, are furnished with large pitchers, which are modified leaves. These contain a watery fluid, and insects falling into the liquid are drowned. Their bodies become decomposed either by the aid of a secretion from glands in the leaf, or by the action of bacteria, and the pitcher absorbs into its tissues the nitrogenous products of the decomposition.

We have, then, to inquire how these processes of digestion, whether internal or external, are brought about.

The protoplasm, among its many properties, no doubt has the power of setting up these decompositions, and probably in many of the lowest forms the work is altogether effected by its instrumentality. Indeed, in every cell of a complex plant the living substance is in a constant state of change, initiating many decompositions in which its own substance takes part, and many others into which it does not enter itself.

Though all protoplasm has this power, it is not usual in plants, any more than in animals, to find it exclusively relying on it. Usually the work is done by peculiar bodies which it forms or *secretes* for the purpose. We have in plants a large number of these secretions, which are known as *enzymes* or *unorganised ferments.*

The action of these bodies is not at all completely understood. They appear to take no part in the composition of the bodies which are formed by their activity, and they seem capable of carrying out an almost indefinite amount of such work, without being used up in the process. They are inactive at a very low temperature, but effect their decompositions freely at the ordinary temperature of the plant. As the temperature rises their activity increases up to a certain point, which varies slightly for each enzyme, and is called its *optimum* point. It usually ranges between 30° and 45° C. If the temperature be raised above that point, the enzymes become less and less active as it rises, and at about 70° C. they are destroyed. They work best in darkness or very subdued light; if exposed to bright sunshine they are gradually decomposed. They are often injuriously affected by neutral salts, alkalies, or acids.

The enzymes are manufactured by the protoplasm of the various cells in which they occur, being produced from its own substance, in a manner somewhat similar to that of the formation of the cell-wall. Usually their presence is manifested by a marked granularity of the protoplasm, due to the formation in it of an antecedent substance, known as a *zymogen*, which is readily converted into the enzyme.

We find various degrees of completeness of differentiation of the cells which produce these enzymes. In the simplest cases, such as the mesophyll of the leaves of most plants, or the seeds of plants belonging to many Natural Orders, or the tubers of the potato, the enzyme is found in all the cells which contain the reserve materials, so that an active transformation of the latter is readily possible. In the horse-radish and many allied plants, the cells which form the enzyme do not themselves contain any reserve materials, but are situated among those which do, giving us as it were the starting-point of glands proper, whose special function it is to secrete these ferments. In some of the plants belonging to the Natural Orders *Capparidaceæ* and *Tropæolaceæ* the glandular cell divides several times to form a little mass or nodule of secreting cells, which must be regarded as a rudimentary gland, though it is not provided with any definite outlet or *duct*.

In the seed of many grasses where there is a special organ, the *scutellum*, to effect the absorption of the nutritive material of the endosperm and supply it to the growing embryo, the outer layer of cells of this organ, called its *epithelium*, is a very marked secreting structure, producing at least two enzymes, which it discharges into the endosperm to effect the decompositions that must precede absorption. The tentacles of *Drosera*, to which allusion has already been made, secrete an enzyme, which, along with a weak acid, is present in the glairy matter that they pour out over the captured insect. These tentacles and the secreting structures of the leaves of *Dionæa* and other plants, and certain similar bodies in the pitcher of *Nepenthes*, must be regarded as actual glands, comparable to those of the animal body, though less complex in structure. Glandular hairs, which consist of a few cells situated on a stalk, are found in great numbers on other plants, especially some species of *Saxifraga*.

There are many of these enzymes present in different plants, the function of some of which is still not understood. Many, however, have been investigated with some completeness. They are usually classified, according to the materials on which they work, into four groups, viz. those which decompose respectively carbohydrates, proteids, glucosides, and fats or oils. In nearly every case the action is one of hydration, the body acted upon being generally made to take up water, and to undergo a subsequent decomposition.

Of those which act upon carbohydrates we have two varieties of *diastase*, which convert starch into maltose ; *inulase*, which forms another sugar, levulose, from inulin ; *invertase*, which converts cane sugar into dextrose and levulose ; *glucase*, which produces grape sugar from maltose ; *cytase*, which hydrolyses cellulose ; and *pectase*, which forms vegetable jelly from pectic substance occurring in the cell-wall. Of the second group *pepsin* and *trypsin* convert albumins and globulins into peptones, the latter decomposing peptone into amido-acids. *Rennet* is probably a member of this group, but its function in vegetable metabolism is unknown. It possesses the power of clotting milk. The enzymes acting upon glucosides are many ; the best known are *emulsin*, *myrosin*, *erythrozym*, and *rhamnase*. The fourth class has only one member which has been investigated at present, the glyceride enzyme that decomposes castor oil.

Diastase appears to exist in two varieties, distinguished from each other by their mode of action on the starch-grain. One called diastase of *translocation*, dissolves the grain slowly from without inwards; the other, diastase of *secretion*, disintegrates it by a process of corrosion before dissolving it. The first of these varieties has a very wide distribution in plants, being present almost everywhere. The second is the body formed by the glandular epithelium of the scutellum of the grasses.

The great function of diastase in the plant is to transform starch (and probably glycogen where it occurs) into maltose, or malt sugar. Wherever starch is formed, whether in the living leaf or in the reservoir set apart for storage, it must be regarded as a reserve material. It has a rather large molecule, but its exact formula is not thoroughly known. The formula $n\ (C_6H_{10}O_5)$ is taken to represent it, and the value of n is probably large. The starch molecule is possibly composed of four amylin or dextrin-like groups, arranged about a fifth. It has been suggested that the first action of the diastase is the liberation of them from each other; and that four of them, by successive incorporation of water, are converted through a series of malto-dextrins into maltose, while the fifth withstands the action of the enzyme for a considerable time. After the enzyme has been acting for a short time the resulting product is found to be four parts maltose and one part dextrin. How far this series of decompositions represents what takes place in the plant is uncertain, but it is clear that the starch, which is insoluble, is converted into sugar, which can be removed to the part of the plant where it is required for building up the protoplasm.

Inulase occurs only in the tubers and roots of some of the *Compositæ*, where inulin is abundant. It appears to convert inulin into *levulose*, an intermediate body being formed in the process. Invertase is easily extracted from the Yeast plant, in which it is abundant. In flowering plants it has been found in the seeds, buds and leaves, and pollen grains. In other fungi than Saccharomyces it occurs in *Fusarum* and *Aspergillus*, besides many bacteria. Its action is the hydrolysis of cane sugar with the formation of dextrose and levulose, according to the equation

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

Glucase occurs in the seed of the Maize. It converts maltose into dextrose.

Cytase is chiefly known in the germinating grain of the barley, where it is secreted by the scutellum and by a layer of cells immediately under the testa. It dissolves the walls of the cells of the endosperm, setting them free and giving a curious mealy character to the grain. Its presence has been detected in the Palms, where large reserves of cellulose are found in the hard endosperm walls. The embryo dissolves these walls and absorbs their products, the exact nature of which however is not at present known. Cytase abounds in certain Fungi belonging to the genus *Botrytis*.

Pectase is but little known, and its function is not very clear. It is recognised by its power of forming vegetable jelly from the pectic bodies of the cell-wall. This jelly appears to be a compound of pectic acid with calcium.

The proteolytic enzymes pepsin and trypsin appear both to be represented in plants, though to what extent the former exists is somewhat uncertain. It is the enzyme which is found in the insectivorous plants *Drosera*, *Dionæa*, and others, and it converts the native proteids of the insect's body into peptones, which are absorbed by the leaf. It only acts in the presence of a weak acid and is only formed by the plant when the gland has been stimulated by the absorption of nitrogenous matter. Trypsin has a much wider distribution, being known to exist in the fruits of the Papau (*Carica Papaya*), the Fig, a variety of the Melon (*Cucumis utilissimus*), and the Pine-apple (*Ananassa sativa*), also in many seeds, such as those of the Hemp, Flax, Barley, and Lupin. In the latter structures it is of especial value in the processes of germination, feeding the young seedling with nutritive proteid or nitrogenous matter until the time when it is able to begin the constructive processes.

It acts upon insoluble proteids, forming from them albumoses, peptones, and amido-acids, such as leucin, tyrosin, and asparagin. The medium in which it works varies according to the source of the enzyme; that prepared from the Papau requires a slightly alkaline one, that from the Lupin works best in a weak acid. These tryptic ferments, no doubt, bring about hydrolysis of the proteid, though it is difficult to prove it by analysis.

Whether rennet is proteolytic it is difficult to say. In the animal body it effects a decomposition of one of the proteids of milk, but the work it does in the plant has still to be ascertained. It has a very wide distribution, existing in the fruits, flowers, seeds, and shoots of various plants.

The enzymes which decompose glucosides are numerous, and are varied in their distribution. A typical one is the emulsin of the bitter Almond and Cherry Laurel, which splits up the glucoside *Amygdalin* according to the equation

$$\underset{\text{Amygdalin.}}{C_{20}H_{27}NO_{11}} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Benzoic aldehyde.}}{C_6H_5COH} + \underset{\text{Prussic acid.}}{HCN} + \underset{\text{Sugar.}}{2(C_6H_{12}O_6)}$$

This is, as in other cases, a process of hydrolysis. This enzyme acts also on other glucosides. Myrosin, another of the group, is peculiar in that it effects its decomposition without apparently causing the incorporation of water in the process; thus:

$$\underset{\text{Sinigrin.}}{C_{10}H_{18}NKS_2O_{10}} = \underset{\substack{\text{Sulphocyanate}\\\text{of allyl.}}}{C_3H_5CNS} + \underset{\text{Sugar.}}{C_6H_{12}O_6} + \underset{\substack{\text{Potassium-}\\\text{hydrogen}\\\text{sulphate.}}}{KHSO_4}$$

Others, such as rhamnase, existing in the seeds of *Rhamnus infectorius*, erythrozym in the Madder, act similarly to emulsin on various glucosides.

The digestion of the glucosides, we may notice, is always accompanied by the formation of sugar, which is one of the products of their decomposition. The fate of the other bodies into which they split is not well ascertained, though there is some evidence that cyanogen compounds, even such as hydrocyanic or prussic acid, are used for nutritive purposes by certain plants.

The digestion of fat or oil has not been very fully investigated, though certain facts are known concerning its fate in germinating seeds. The digestion is generally accompanied by the production of starch-grains in cells near the seat of digestion, and it was formerly considered that the starch arose directly from the oil. It appears now that the oil is split up by an enzyme, with the formation of a free fatty acid and glycerine. The fatty acid undergoes further decomposition, being probably oxidised into simpler acid bodies which are crystalline instead of being viscid like the fatty acid first liberated. These pass into the general body of the seedling. The glycerine in its turn is possibly converted into some form of sugar, from which the plastids of the seedling construct the starch which has been referred to, its formation indicating, as in other cases, a temporary surplus of carbohydrate supplies.

Recently another class of enzymes has been discovered, which are instrumental in carrying out many of the processes of oxidation. These have been consequently called *oxidases*.

There are other enzymes with a more restricted distribution about whose value to the plant little or nothing is at present known. The cells of a particular micro-organism, known as *Torula Ureæ*, decompose urea with the formation of ammonium carbonate, and an enzyme having the same power can be extracted from them. Many enzymes can be prepared from bacteria, which set up various changes in proteids, partly peptonising and partly putrefactive.

The production of alcohol from sugar, which is so characteristic of the metabolism of the yeast cell, has recently been shown to be due to the action of an enzyme which has been called *zymase*. This body exists not only in the cells of the yeast plant, but in those of many ripe fruits. Probably its distribution will be found to be more extensive than is generally supposed.

The fermentative activity of the protoplasm was alluded to at the opening of this chapter. It leads to the formation of acetic acid from alcohol by the fungus *Mycoderma aceti*, and of other acids in the cells of the higher plants. The dependence of these fermentations upon the vital activity of the protoplasm is evident from the fact that no enzyme can be extracted from any of these cells which can set up the particular changes in question.

It is not difficult to prepare the enzymes from the tissues in which they work, but it would be extremely rash to say that they are in anything like a pure condition when obtained. Nor is it easy to say much about their purification, as they are not known except in close connection with the substances on which they act, or with the products of the decompositions they initiate. There is, therefore, no criterion of their purity.

They can be extracted by treating the tissue, which should be very finely divided or ground in a mortar, with glycerine or with solution of common salt, or with water containing a trace of an antiseptic. After a period of ten or twelve hours the extract should be strained and subsequently filtered, when the enzyme may be precipitated by strong alcohol. It is very evident that this will not yield it pure, for the solvents employed will dissolve many constituents of the tissue besides the enzymes, particularly proteids and sugars. The former will be thrown down with the enzyme by the alcohol.

The actual incorporation of the food into the living substance, or the renewal and construction of the protoplasm at the expense of the food, is not at present understood.

CHAPTER X.

THE CATABOLIC PROCESSES.

We have seen that the object of all the processes of construction and digestion that we have examined so far has been to present to the protoplasm materials which it can incorporate into its own substance. The bodies which we have traced to it consist, in far the greatest part, of some form of sugar and of organic nitrogenous bodies, either proteids or the complex products of their decomposition, such as the amido-acids. The protoplasm of the cell is continually reconstructing itself at the expense of such nutritive substances, which indeed constitute its food in the strict sense of the term. But there is also going on, side by side with this process of reconstruction, a decomposition of the substance of the protoplasm, involving a splitting off from its complex molecule of various bodies of great variety but of less complexity than the living substance itself. These often, in the first instance, include such carbohydrate and nitrogenous residues as it made use of in building itself up. These can again be used in reconstruction of the protoplasm or can be further broken down into simpler bodies still. So long as the protoplasm is living, it is constantly in a state of change or chemical activity, undergoing reconstruction and decomposition continually.

Besides this power of initiating chemical changes in which it takes itself a prominent part, it is also the seat of a large number of processes of both oxidation and reduction which are always going on in its meshes at the expense of the various materials which are found there, either from being transported from other cells or from being formed in the processes of the self-decomposition of the protoplasm.

The formation of simpler from more complex bodies by either of these methods constitutes what has been called the *catabolism* of the plants. It may sometimes go on to the extent of producing such simple bodies as carbon dioxide and water, which are given off from the organism. In most cases, however, the catabolic changes are not so far-reaching, and there remains in the plant a great accumulation of organic substance such as woody or corky tissue. The relatively small extent of the catabolism as compared with the anabolism finds its expression in the enormous bulk which many trees and other plants attain.

Some of these processes of catabolism or, as it is sometimes called, *destructive metabolism*, are directly applied to the production of substances which are of great use to the plant. The formation in this way of materials which are of value to the organism is generally called *secretion*. In other cases bodies are produced which are of no value to the plant and which are as far as possible withdrawn from the spheres of vital activity. Comparatively few of them are ever thrown off from the plant, but they are generally deposited in such regions as leaves which are about to be shed, or the bark of trees, which is a collection mainly of dead matter, or sometimes in special cells, or in cell-walls, or elsewhere. These bodies really correspond to excreta, and the processes of their formation are called processes of *excretion*. Many others occur whose meaning is still obscure, and these constitute what are often called the *bye-products* of metabolism.

Of the processes of secretion the most prominent perhaps is that of the formation of cell-walls. We have seen that in the division of a cell in any of the higher plants the nucleus divides by a series of complicated movements, and forms two daughter nuclei, which are at first connected together by a structure called the *spindle*. Along the fibrils of this spindle minute particles or granules, originating in the protoplasm, pass to form a plate of extreme tenuity across the cell midway between the two new nuclei. This plate soon undergoes a transformation into the ordinary cellulose of the plant. The cell-wall is thus seen to be formed from the protoplasm, or to be *secreted* by it, the granules of which it is at first composed being the result of decomposition set up in the living substance.

When cell-walls are growing in thickness or in surface, a similar decomposition of the protoplasm can be observed. Fresh granules can be seen to be deposited by the latter upon the surface of the original cell-wall, which are soon transformed into the first thickening layer of cellulose. In all cases, therefore, the formation of cellulose can be traced to the self-decomposition of the protoplasm.

A very similar phenomenon is observable in the formation of starch-grains. In most cases this is brought about by the activity of a plastid, either a chloroplast or a leucoplast. We have seen that these structures may be regarded as specially differentiated protoplasmic bodies, and their mode of behaviour has been described. Building themselves up at the expense of sugar and probably nitrogenous residues remaining in the meshes of their substance, they break down to a certain extent, splitting off a quantity of starch which is poured out by the leucoplasts or deposited in their interior by the chloroplasts, leading to the appearances already described. The formation of starch is thus a secretion by the plastid, just as that of cellulose is a secretion by the protoplasm of the cell. In those cases where small grains of starch are formed without the intervention of a plastid, the work is done by the protoplasm of the cell.

The most recent researches render it highly probable that the formation of aleurone grains is precisely similar in the way in which it is brought about.

The formation of fat is due to similar behaviour on the part of the protoplasm. It can be observed most easily in the case of certain Fungi, when they are not well nourished. The protoplasm is found to get less in amount, the vacuolation becomes very considerable, and the cavities are found to contain large drops of oil. The elaioplasts to which reference has been made behave similarly, their substance diminishing at the same time that fat or oil makes its appearance. The decomposition of the protoplasm is here not accompanied by much reconstruction, so that it is soon very greatly diminished in amount, while the fat, the product of the catabolic processes, increases.

The formation of the enzymes described in the last chapter is another instance of the same kind. These are gradually elaborated by the protoplasm from its own substance, their development being attended by the formation of granules much as is that of cellulose.

One of the most important of these secretions is the green colouring matter, *Chlorophyll*, which we have already seen is present in the form of a solution in the meshes of the chloroplasts. The formation of chlorophyll is a more specialised process than any of those which we have just been considering, and is dependent upon a variety of conditions. It probably involves not only the self-decomposition of the protoplasm, but also other processes taking place in its meshes.

The conditions necessary for the formation of chlorophyll are, 1st, access of light; 2nd, a particular range of temperature; 3rd, the presence of a minute quantity of iron in the plant. If a plant be cultivated from seed in darkness, the resulting seedling will not be green, but will have a yellowish-white colour. When examined by a microscope the plastids will be found in the cells, but they will be tinged with a pale yellow pigment known as *etiolin*. When the etiolin is exposed to light it will rapidly become green, being in fact replaced by or converted into chlorophyll. The etiolin is in the first instance secreted by the protoplasm of the plastid, and subsequent changes take place about which little is known, converting it into chlorophyll. If the temperature be kept very low, the etiolin remains unchanged, even though light be admitted. Hence the first leaves of plants which spring up in the winter are frequently yellow and not green. The function of the iron is not understood; plants cultivated in such a medium that this element is not supplied to them have an appearance much like that of an etiolated plant. Their colour is even paler, indeed they are almost colourless, though the plastids are present. A supply of iron at once changes them to the normal appearance. Plants so suffering from the absence of iron are said to be *chlorotic*.

The excretions of plants, using the term in the wide sense indicated above, and not implying that they are thrown off from the plant body, are similarly produced. Perhaps the most frequently occurring instance of these is the sugary solution known as the nectar, which is so common in flowers. Other instances are the resin produced in the resin glands of the Conifers and of other trees, and the etherial oils found in special receptacles in the leaves and other parts. Mineral matters, chiefly carbonate and oxalate of calcium, are also formed. The carbonate is in some cases excreted on to the surface through special glands, as in certain Saxifrages; in others it is deposited in the substance of the cell-walls or of protrusions from them, as in the cystoliths of Ficus, the Nettle, and other plants. The oxalate is frequently deposited in special cells, where it forms the bodies described as raphides and sphæraphides. In these cases the cluster of crystals is usually invested by a delicate skin derived from the protoplasm. The oxalate is also sometimes deposited in the substance of the cell-wall as in the bast fibres of *Ephedra*. Silica, again, is accumulated in the epidermis of many grasses and Equisetums.

Many of these excretions cannot be traced to the self-decomposition of the protoplasm, but are probably formed by the processes of oxidation and reduction which we have seen are often associated with its activity. They are not, however, formed without its intervention in some way.

The bye-products of metabolism are too numerous to be discussed in detail in the present treatise. They include bodies of varying degrees of complexity, some nitrogenous, others not. Among the former may be mentioned many compounds of the amides with fatty acids, xanthin and bodies allied to it, and the great group of the alkaloids. It is possible that many of these may be of use to the plant in its processes of reconstruction, but some are certainly of no value in this respect. The alkaloids come under the latter category, for though they contain combined nitrogen they cannot minister to the growth of the plant. If a plant is supplied with them, but with no other form of combined nitrogen, it is rapidly starved. The amido-acids, leucin, tyrosin, glycin, &c., on the other hand, can be absorbed and utilised in the processes of nutrition. The latex of plants frequently contains many of these bodies. Caoutchouc is also present in some.

Among the non-nitrogenous bye-products may be mentioned the great variety of vegetable acids and many of the glucosides, such as salicin, coniferin, &c., which have a certain nutritive value owing largely to the sugar they contain. Many other products derived from them may also be utilised in this way. Such bodies may perhaps be best included among the reserve materials already discussed. The vegetable acids, such as tartaric, malic, citric, &c., are usually regarded as arising in the course of the catabolic processes; it is, however, possible that some of them may be formed in the elaboration of food from the raw materials absorbed, having thus their origin in anabolism.

The bye-products include also a variety of aromatic substances, such as tannin, phloroglucin, and aromatic acids, such as benzoic, salicylic, &c., but the nature of the processes which give rise to them is not well understood.

Certain decomposition products of cellulose may also be included here. The lignin and suberin, which are characteristic of woody and corky cell-walls, arise in this way. During their formation they can be removed by appropriate solvents, leaving the cellulose skeleton which they are gradually replacing. These differ from most of the bodies described in that they can be produced in the walls of cells that have lost their protoplasm, so that their formation is independent of the latter.

Finally, we may include here the odorous substances and the colouring matters, except chlorophyll. Many colouring matters are the products of the decomposition of the latter, especially *xanthophyll* and *erythrophyll*, to which the autumn tints of leaves are due. The former appears to be always present with chlorophyll in the chloroplasts.

Though many of these substances, both excretions and bye-products, are of no value for nutrition, some of them may play a very important part in the defence of plants against their natural enemies, their nauseous smell or flavour preventing their being eaten by animals, &c. Some odours and the nectar found in flowers are doubtless of great service in attracting insects, which assist in the process of cross-pollination, to be discussed in a subsequent chapter.

CHAPTER XI.

THE RESPIRATION OF PLANTS.

One of the conditions of life of almost every organism, whether animal or vegetable, is that it shall be supplied with free oxygen. Not only do all the vital activities of plants as well as animals depend upon this, but the very life of the protoplasm ceases if this gas is withdrawn. Consequently, as long as life is maintained, the organism must be continuously absorbing oxygen. This is very evident in the case of an animal, but it is not so obvious in that of a green plant, for the process of decomposing the carbon dioxide taken in as a material for food construction is, as we have seen, accompanied by an evolution of oxygen. In the case of a plant which has no chlorophyll the absorption of oxygen can be much more easily detected, as it is not masked by this converse process of its exhalation. If a fungus, such as a mushroom, be placed in a closed receiver containing ordinary air, and be left there for some hours, at the conclusion of the experiment the vessel will be found to contain but little oxygen, which will have been replaced by about an equal amount of carbon dioxide. It is not difficult to devise an experiment which will show that a green plant has the same absorbing power. If the light be excluded from one placed in a similar vessel, no evolution of oxygen will take place from it, as we have already noticed in a preceding chapter, and that the oxygen diminishes even to extinction can be made evident just as in the case of the mushroom. We have, however, evidence that this is not caused by the exclusion of the light. An apparatus can be easily arranged to show the absorption of oxygen even when a green plant is exposed to a bright sunlight. The atmosphere in which the plant is placed can be freed from carbon dioxide by having a vessel containing a solution of caustic potash in the receiver with the plant. The potash will absorb the carbon dioxide of the original atmosphere admitted, as well as any given off by the plant during the experiment. If a capillary tube be fitted into the receiver and its other end be made to dip into a vessel of mercury, the latter will slowly and gradually rise in the tube, indicating a diminution of the volume of the included air. If the experiment be continued till the mercury ceases to rise in the tube and the gas remaining in the receiver be measured at the ordinary atmospheric pressure, it will be found that its volume has been diminished by about 20 per cent. and that what is left consists of nitrogen. The oxygen will have been completely removed by the green plant, even when in sunlight. If the caustic potash be examined, it will be found to have gained considerably in weight and to contain a quantity of carbonate of potassium. Thus there has been proceeding an absorption of oxygen, attended as before by an exhalation of carbon dioxide, the latter having been combined with the potash.

This process of gaseous interchange constitutes what is known as *respiration*. Though more easily detected when the absorption of carbon dioxide and its decomposition by the chloroplasts are suspended, it is nevertheless constantly going on so long as the plant is living. It is observable in all living parts of the plants, whatever be their environment.

If the plant be carefully weighed at the beginning and end of the experiment, it will be found to have lost weight during its stay in the receiver, so that respiration is associated with a loss of weight to the plant. Not only is respiration attended with the emission of carbon dioxide, but there is also a certain exhalation of watery vapour, which takes place quite independently of any supply from the root or the cut end of the stem. The nature of the metabolism is such that the living substance gives off both water and carbon dioxide while it coincidently absorbs oxygen. This is quite independent of any constructive processes, for it can be observed when no nutritive material of any kind is supplied to the plant.

We may inquire what is the relation of the absorption of oxygen to the elimination of carbon dioxide and water. It is conceivable that the oxygen may unite in the plant with carbon and with hydrogen to produce at once the exhaled compounds.

A study of the living organism at work, however, soon shows us that the process is not of this simple nature. If a study be made of the germination of starchy seeds, the volume of oxygen absorbed is about equal to that of carbon dioxide evolved, but if oily seeds be examined during germination, more oxygen is taken in in proportion to the carbon dioxide given out. Various observers have shown that in certain cases, succulent leaves, or the phylloclades of a Cactus, are capable of absorbing oxygen without the simultaneous evolution of carbon dioxide at all. Nor is the oxygen absorbed without entering into chemical combination, for it cannot be extracted by the air-pump. Conversely carbon dioxide may be thrown off from a plant without any simultaneous absorption of oxygen. If a seed be germinated in a vacuum over a column of mercury, carbon dioxide is found to be evolved. Ripe fruits have been found to give off carbon dioxide in an atmosphere quite devoid of oxygen.

Again, it is found that the ratio of oxygen absorbed to carbon dioxide exhaled varies according to the temperature at which the experiment is conducted. Evidently the two processes are not directly dependent upon each other.

It is evident from the foregoing consideration that the vital activity of protoplasm is somehow associated with the two processes. In the absence of oxygen it gradually ceases, the living substance being in fact slowly asphyxiated. During its life one of the manifestations of its metabolism is the formation and exhalation of the two fairly simple compounds carbon dioxide and water. To ascertain what is the true relation of the two processes, it is necessary to look closely at the nature of the chemical changes going on in the protoplasm itself, or at what we have called its metabolism.

Respiration in the strict sense is, therefore, a process going on in the living substance itself, or rather is the expression of the beginning and end of a series of complex changes in which the molecules of the living substance are involved. The details of the absorption of the oxygen by the plant from its environment and the ultimate evolution of the carbon dioxide and water from the plant body should rather be regarded as the mechanism of respiration than respiration itself, which is a function of the living substance only.

We see, then, that the two processes are not immediately connected in the sense of the carbon dioxide coming at once from the direct oxidation of carbon, but that they are ultimately associated, though separated in time by a series of chemical changes taking place in the living substance.

In the metabolic changes going on in the protoplasm we find, however, that while its own molecules are in a constant state of decomposition and reconstruction, other changes also take place in the various substances which are enclosed in its meshes, into which its own molecules do not enter. Processes of slow oxidation and gradual reduction are taking place there continually, excited, nevertheless, in all probability by the changes in the protoplasm itself. Even these are by no means simple, and the direct oxidation of either carbon or hydrogen has probably no place amongst them. An instance of them may be seen in the oxidation of alcohol in the cells of *Mycoderma aceti*, a fungus which converts alcohol into acetic acid. This process, into which the molecule of protoplasm can apparently not enter, nevertheless can only go on in the living cell. Other similar instances could be quoted.

The probable course of events is that the oxygen in some way unites with the molecule of protoplasm, rendering it unstable and initiating a series of decompositions which result in the formation of many of the bodies already spoken of in the last chapter. If the temperature be low, the breaking down of the protoplasm proceeds but slowly, and reconstruction, either from some of these residues or from food supplied to it from the cell contents, or both, is rapid. Consequently the quantity of oxygen absorbed or fixed by the protoplasm is greater than the quantity of carbon dioxide formed by its decomposition. At a higher temperature decomposition is much more easily carried on and its products are more numerous and simpler. The decomposition and recomposition go on side by side, simpler bodies being gradually produced, either by their splitting from the protoplasm directly, or by their being formed at the expense of the more complex decomposition products, during processes of slow oxidation in its meshes, till finally a certain production of carbon dioxide and water is arrived at. So long as the protoplasm remains alive the amount of these is not large, reconstruction continually taking place. When, however, the protoplasm dies, simpler bodies such as carbon dioxide, water, and possibly *Ammonia* in addition, are produced abundantly from the decomposition which attends its death.

The carbon dioxide is thus the final term in a series of decompositions of which the living substance is the seat, and which are promoted by the access of oxygen. In some cases, such as that of the Cactus already alluded to, this final term is not reached, no carbon dioxide being exhaled. In these cases the process stops short at the formation of certain organic acids which are found in abundance in the tissues of the plant.

The meaning of these complex metabolic processes must be looked for in relation to the question of the energy which the plant requires for its vital functions. There are but two sources of energy available for its use; one of these, the radiant energy of the sun's rays, can only be utilised through the chloroplasts, and is not directly at the disposal of the protoplasm. But the construction by them of various complex materials, food and plant substance, involves the expenditure upon the latter of a considerable amount of this energy, which can be again set free by the decomposition of the complex bodies and the production of simpler ones from them. It is, of course, an every-day experience that the combustion of coal or wood, which is really the oxidation of its carbon and hydrogen to the condition of carbon dioxide and water, is attended with the liberation of a great deal of energy which takes the form of heat. So with the decompositions of the protoplasm which are set up, or at any rate facilitated, by the access of oxygen. The splitting up of the complex molecule, and the formation of simpler ones, at once set free certain potential energy, the amount being proportionate to the extent of the changes. Part of this energy is required at once by the protoplasm for the reconstruction or building up of its substance from some of the residues, but as some comparatively simple bodies, such as carbon dioxide and water, are always left to be given off, there is always liberated a certain amount of energy available for other work. In many cases this takes the form of heat. In germinating seeds and in the opening of flower-buds, where respiration is particularly active, there is constantly an appreciable rise of temperature, sufficient indeed to be measured by a thermometer. In other cases the released energy is utilised in causing movement; in a few instances occurring among certain fungi, it takes the form of light or phosphorescence.

The importance of respiration thus becomes evident; it marks the initiation, and is the accompaniment, of the catabolic processes which we have discussed in the preceding chapter, and these coincidently place at the disposal of the plant a certain store of energy which, originally derived from the radiant energy of light, has been transformed from the kinetic to the potential condition, and which is rendered again kinetic by the catabolic changes. So constant is this relation that it may be said that heat is always evolved where and while oxygen is being absorbed.

Though respiration is always proceeding wherever there is living protoplasm, the activity of the process is modified by different physical conditions. The degree of illumination of most plants is continually varying, and though respiration does not depend upon light, its activity is not the same under all conditions of the latter. We have already noticed that variations of temperature affect differently the absorption of oxygen and the exhalation of carbon dioxide. The absorption of oxygen is suspended if the temperature is too low, it increases as the latter rises to a certain optimum point, which varies with different plants. and at higher temperatures it progressively decreases. The exhalation of carbon dioxide is smaller at low temperatures than the absorption of oxygen, but is greater at higher ones.

The process of respiration is also affected to a considerable extent by the nature of the substances which serve as nutritive material for the reconstruction of the protoplasm. It has already been pointed out that seeds containing oil absorb more oxygen during germination than those whose reserve material is largely starch. Organs which contain much proteid matter respire more copiously than others which contain but little. The nature of the inorganic salts absorbed also influences the process to a certain extent.

The importance of respiration thus appears to be that it is one great means whereby the stored energy is made available by the protoplasm of the plant. Strictly speaking, it is immediately dependent upon the access of oxygen to the latter. We find, however, that absorption of oxygen is not universal. In the case of certain micro-organisms it does not take place; indeed, these so-called *anaërobic* plants are killed by exposure to the gas. We must not, however, conclude that their metabolism is of a totally different kind from that of others, but rather that they obtain what energy they require from other internal decompositions. Many parts of green plants can show a similar behaviour when oxygen is denied access to them. The partial asphyxiation which sets in causes another series of decompositions, known by the name of *alcoholic fermentation*. The protoplasm in these cases decomposes such sugar as may be present in the cells, splitting it up into alcohol and carbon dioxide. That this is attended by the liberation of energy is seen by the fact that a certain amount of heat is always generated during the progress of the fermentation. Nor is alcoholic fermentation the only one met with, though it is the commonest. Other fermentative changes are brought about in the case of other anaërobic organisms.

The action of the protoplasm in setting up alcoholic fermentation is probably not direct. In many cases, especially in those of yeast and of certain fruits, it accomplishes the decomposition of the sugar by secreting a peculiar enzyme called *zymase*, which can by appropriate methods be extracted from the cells and can set up the fermentation while quite free from the plant.

CHAPTER XII.

GROWTH.

In studying the growth of plants we must consider the relation which it bears to the processes of metabolism which we have already discussed. We have seen that the constructive metabolism or anabolism is much greater than the destructive, or catabolism. There results from this a considerable increase in the substance of the plant, as well as an accumulation of potential energy which can be made available by the plant by the destructive processes. Usually we have therefore a great accumulation, which is primarily manifested in growth. Here again we must distinguish between the growth or increase of the living substance and the manufacture of other products such as wood, which are not necessarily living.

The growth of the living substance is always the result of constructive metabolism, and is attended by an increase of bulk and weight. The growth of an organ sometimes appears to be independent of such increase of weight; indeed, a diminution of the weight of the whole structure is sometimes noticeable. Thus, in the case of a potato allowed to germinate in such conditions as prevent the absorption of food materials from without, we have a marked change of form, but owing to the loss of moisture by transpiration and of carbon dioxide as a consequence of its respiration, or the catabolic processes going on in it, the resulting plant may weigh much less than the original potato.

This difference is, however, rather apparent than real. We shall see that the actual growth, or the manufacture of new cells, is confined to certain regions. In these regions there is a considerable increase in bulk and weight, but as the materials which are used for the purposes of this local growth are derived from substances stored up in the body of the tuber, the latter, which is not the seat of the growth at all, diminishes in weight and size to such an extent as more than to counterbalance the gain in the growing regions. Hence the whole plant weighs less than the tuber, though considerable growth may have taken place.

Growth is in the strict sense, then, always associated with the formation of new substance; it is in nearly all cases attended by a permanent change of form. This is perhaps not so evident in the case of axial organs, though here it takes place to a certain extent, as it is in that of leaves and their modifications. In most cases the young leaves of a plant have a different shape from the adult ones, and the appearance of the latter is gradually assumed as the leaf grows older.

This change of form not only can be seen in the case of such an organ as a leaf, but may be noticed also in that of the individual cells of which a plant consists. In the apical meristem of the shoot of a flowering plant the cells when first formed are almost cubical; after a little while we find many of them becoming prosenchymatous. Many other cases can be noted, particularly the irregularly shaped cells of the spongy parenchyma of leaves, the stellate cells of the pith of certain Rushes, the laticiferous cells of the Spurges, &c.

Growth may, in the light of the considerations advanced above, be defined as *permanent increase of bulk attended by permanent change of form*. We must not assume that increase of bulk is necessarily growth, for, as we shall see, in growing cells and members there is a constant stretching of the cell or tissue by hydrostatic pressure or turgidity which can be distinguished from growth by the fact that it can be removed, with the result of a certain amount of shrinkage of size of the part under examination.

Growth in the lowliest plants may be coextensive with the plant body. In all plants of any considerable size, however, it is localised in particular regions, and in them it is associated with the formation of new protoplasts. We have already seen in the case of the sporophytes of all the higher plants that there exist certain regions in which the cells are merismatic, that is, which have the power of self-multiplication by means of division. In such regions, when a cell has reached a certain size, which varies with the individual, it divides into two, each of which increases to the original dimensions and then divides again. These regions have been called *growing points*; they may be apical, or intercalary, or may consist of definite layers known as *cambium* layers, or *phellogens*. By the activity of the protoplasts in these merismatic areas the substance of the plant is increased. As they consist of cells, it is evident that the growth of the entire organ or plant will depend on the behaviour of the cells of which it is composed.

The growth of a cell will be found to depend mainly upon four conditions: 1. There must be a supply of nutritive or plastic material at the expense of which the formation of protoplasm can take place. 2. There must be a supply of water to such an extent as to set up a certain hydrostatic pressure in the cell. This condition we have already considered in the first chapter of this section, where we discussed the relation of protoplasm to water. In the absence of this *turgescence* no growth is possible, for reasons that will presently appear. 3. There must be a certain temperature in the plant, for the activity of protoplasm can go on only within certain limits, which differ in the cases of different plants. 4. There must be a supply of oxygen to the growing cell, for, as we have seen, the protoplasm is dependent upon this gas for the performance of its vital functions. This is evident from the consideration that the growth of the cells is attended by the growth in surface of the cell-wall, and as the latter is a secretion from the protoplasm, a product, that is, of its catabolic activity, such a decomposition cannot readily take place unless oxygen is admitted.

When these conditions are present the course of events appears to be the following: the young cell, immediately it is separated from its fellow, absorbs water, and with the water its contained nutrient substances. There is set up at once a certain hydrostatic pressure due to the turgidity, and the extensible cell-wall stretches, at first in all directions. The growth of the protoplasm at the expense of the nutritive matter for a time keeps pace with the increased size of the cell, but by and by it becomes vacuolated as more and more water is attracted into the interior. Eventually the protoplasm forms usually only a lining layer to the cell-wall, and a large vacuole filled with cell-sap occupies the centre. The growth of the protoplasm, though considerable, is therefore not commensurate with the increase in size of the cell. The stretching of the cell-wall by the hydrostatic pressure is fixed by secretion of new particles upon the original wall, which as it thus becomes slightly thicker is capable of still greater extensibility, much in the same way as a thick band of india-rubber is capable of greater stretching than a thin one. The increase in surface of the cell-wall is thus due firstly to the stretching caused by turgidity, and secondly to the formation of new cellulose upon the old. The latter only is the growth of the cell-walls ; the former can be removed by irrigating the cell with a solution of a substance, such as common salt, which will rob the cell of the water it contains. The constructive changes leading to the formation of new protoplasm are attended in this process by the catabolic formation of cell-wall and other substances, such as the osmotic bodies which are necessary to attract the water into the cell. The supply of oxygen is needed to allow the protoplasm to undergo these catabolic decompositions, enabling it thus to produce these several products and to gain from such decompositions the energy which must be expended upon the construction and reconstruction of the living substance and used in the secondary chemical changes which supervene.

This process of the growth of a cell is limited in its extent, though the limits vary very widely. In some cases cells grow only to a few times their original dimensions; in others they may attain a very considerable size. In any case, however, we can notice that the rate of growth is not constant; it begins slowly, increases to a maximum, and then becomes gradually slower till it stops. The time occupied by these varying rates of growth is generally spoken of as the *grand period of growth.*

Changes in the shapes of cells arising during growth depend upon two factors. The direction of hydrostatic pressure and the power of the cell to respond to it may not continue the same in all directions, and, consequently, the growth of the cell in the direction of greater pressure or least resistance will be greater than elsewhere. The extensibility of the cell-wall may also be locally modified by the protoplasm, so that the growth becomes irregular, and cells of curious form may result.

If we consider the behaviour of a growing organ in the light of these facts, we shall see that it, like the cell, must show a grand period of growth. If we take the case of a root, in which the changes can be traced most easily from the simplicity of its structure, we find that just behind the apex the cells are all in active division. Growth is small, for the cells divide again as soon as they have reached a certain size. As new cells are continually formed in front of the merismatic mass, those behind gradually cease to divide, and the process of growth proper takes place. Here the actual extension in length of the root goes on, and the cells are at the maximum point of their grand period. They then gradually lose the power of growth, the oldest ones, or those furthest from the apex, parting with it first, and they pass over into the condition of the permanent tissue. Thus every portion of the root goes through a grand period of growth; at first, when the cells are merismatic, growth is at a minimum, it gradually becomes accelerated, reaches a maximum, and slowly ceases, exactly as did that of the cell which we first considered. By careful examination of a growing root it can be found that the growth is greatest just behind the merismatic region. If a young root be taken and marked with a series of dots at equal distances apart, and then allowed to continue its growth, it will be found that the dots remain close together at the apex and for a very short distance from it. Then they become separated by broader spaces. Further back still the original intervals between the dots are again unaltered. The second region corresponds to the part where the cells are undergoing the enlargement described.

The same order of events may be ascertained to take place in the stem, but in this region it is complicated by the occurrence of nodes and internodes. Growth in length is confined to the latter, each of which passes through a similar grand period. The growth of the stem is the algebraical sum of the growth of the internodes, many of which may be growing simultaneously. They will consequently be at different parts of their grand period at any particular moment. The region of growth in the stem is, as a rule, much longer than that of the root.

The growth of the leaf shows a little variation. The apical growth is commonly not very long continued, and the subsequent enlargement of the leaf is due to an intercalary growing region near the base. This area has the merismatic cells at about its centre, and regions of greatest growth are on both sides of it. This can be traced more easily in the elongated leaves of Monocotyledons than in those of Dicotyledons.

The grand period itself is not quite uniform, as the rates of growth in the active region may and do vary with changes in external conditions, and with differences in activity in the protoplasm from time to time. This can be observed very favourably in the case of a young stem, which grows most quickly during the night and more slowly during the day. The variations are fairly regular, and constitute what has been called the *daily period of growth in length*.

For the sake of simplicity of description it has been assumed in the foregoing account that the turgidity of the cells in the growing organ is uniform. This, however, is far from being the case. There is generally a fairly regular variation in this turgidity in the different parts of the growing organ. In the simplest case we may consider one which shows a difference in structure on two sides; such a member is described as *dorsiventral*. The two sides will often show a difference of degree of turgidity, and consequently of rate of growth. If we consider a leaf of the common Fern, we find that in its young condition it is closely rolled up, the upper or ventral surface being quite concealed. As it gets older, it gradually unfolds and expands into the adult form. This is due to the fact that in the young condition the turgidity and consequent growth are greater on the dorsal side of the leaf, so that it becomes convolute. As it gets older the maximum growth changes to the upper side, and so it becomes unfolded or expanded. These two conditions are generally described under the names of *hyponasty* and *epinasty* respectively.

These conditions are not confined to the leaves of ferns, but may be detected in those of other plants, though to a less degree. It is in consequence of them that the leaves of the bud always fold over the apex of the stem from which they spring.

Cylindrical organs may exhibit similar variations in growth. One side of a stem may be more turgid than another, and the maximum turgidity with its consequent growth may alternate between two opposite sides. The increased turgidity of the cells is often accompanied by an increased extensibility of the cell-walls of the turgid region. The growing apex of such a stem will alternately incline first to one side and then to the other, exhibiting a kind of nodding movement in the two directions. This is known as *nutation*, and it is of very frequent occurrence.

The region of greatest turgidity, instead of being alternately on one side and the opposite, may pass gradually round the growing zone. The apex in this case will describe a circle, or rather a spiral, as it is elongating all the time, pointing to all points of the compass in succession. This movement has been described by Darwin as *circumnutation*, and has been said by him to be universal in all growing organs. The passage of the maximum turgidity round the stem may be regular or irregular, causing the circle to be replaced by an ellipse. Indeed, the simple nutation spoken of above may be regarded as only an extreme instance of the latter.

By these movements, incident to growth, and proceeding altogether from internal causes, many advantages are secured to the plant. In the case of climbing stems the circumnutation enables them to reach supports round which they twine, so that with but little expenditure of substance they can secure advantages of light and air which they could not obtain in its absence. The roots by the same method are enabled more easily to make their way through the crevices of the soil. The axis of the embryo shows in one or other of its parts strong hyponastic curvature, forming an arch, which enables it to leave the seed coats and make its way through the soil without damage to the young delicate plumule, its progress being helped by simultaneous circumnutation. On reaching the surface epinastic growth causes it to assume the erect position, while circumnutation of the apical region replaces that of the arched portion of the axis.

During the period of growth the young organ is extremely sensitive to changes in its environment, responding to such stimulating influences by further modifications of its behaviour; these will be considered in detail in the succeeding chapter.

Besides the hydrostatic tension set up in the cells of the growing regions, the processes of growth are accompanied by other tensions existing in their interior, which appear to depend upon differences between their tissue systems as these develop. If a petiole of Rhubarb be taken, and a thin strip be peeled from one side, it will immediately curl outwards. If it be then placed in apposition with the part from which it was cut, it will be found to be appreciably shorter than the rest of the petiole. If the petiole be carefully measured, and then deprived of its cortical covering by separation of successive strips, the central part when measured will be found to be slightly longer than the original petiole. In such a petiole the central part was clearly compressed by the external portions, and when these were removed it underwent an extension which was the expression of the amount of such compression. Similarly the external parts were stretched longitudinally by the central region, and when they were freed from it, the recoil was accompanied by a diminution of their length. There was thus a longitudinal tension in the petiole, due to the turgescence of the central part, which stretched the outer portions, and was itself compressed by their greater rigidity resisting the hydrostatic extension. This tension is due not to greater growth, but to increased turgidity, for if the petiole be soaked for a while in salt solution till the water is in great part removed from its interior, and it has become flaccid, removal of the cortex is not accompanied by the same changes of dimension. A similar experiment may be performed on the hollow flower-stalk of a Dandelion. If it be slit into two halves by a vertical cut, the two parts curl outwards from each other, showing a similar tension in the internal regions.

Transverse tensions in growing stems can also be demonstrated. The cortex is found to be strained outwards by the pith, so that if a ring of it be cut out of the stem, it will be seen to shorten on removal. The pith is in a state of compression, and the cortical tissues in one of extension, as in the other case quoted above. Transverse tensions of this kind are set up in the course of the thickening of stems and roots by the activity of the cambium layer, the bast and cortex being compressed outwards and the wood compressed inwards on account of the formation of the new material. This gives us a partial explanation of the formation of the annual rings of such stems and roots, and of the ruptures that are generally noticeable on the exterior of such parts.

In the absence of the external stimulating influences referred to above, growing organs show a tendency to grow in straight lines. Though the apex of any of them may continually show the movement of circumnutation, the mature part generally takes up a fixed position, growing vertically or horizontally as the case may be. This position is, however, usually the resultant of a number of external forces acting upon the growing organ. The inherent tendency just spoken of can be satisfactorily seen only when, by artificially eliminating the action of such forces, the plant is not exposed to their stimulating influence. Such a tendency has been called *Rectipetality*.

CHAPTER XIII.

INFLUENCE OF THE ENVIRONMENT ON PLANTS.

According to the nature of their surroundings and the consequent differences in mode of life, we find in many plants certain peculiarities of form and structure which are different from those of the bulk of the forms which we have hitherto considered. Of these the Spermaphytes which live in water may be first discussed, as the direct influence of their environment is most conspicuous in their case.

These aquatic Phanerogams may be divided into two chief groups: those which are altogether submerged, and those which bear floating leaves as well as or instead of submerged ones.

In the former case the plant body may be attached by roots to the bottom of the stream or pool, or may be altogether floating. The stems are almost invariably long and slender, and easily swayed to and fro in the water. They depend for their support upon the nature of the medium in which they live, and though possessing a certain rigidity, this is not associated with any great development of woody tissue. Generally the latter is reduced to a minimum; the fibro-vascular bundles are usually few and contain few lignified elements. The substance of the plant is largely parenchymatous, and the cells have thin walls. The intercellular space system is often very complex, large lacunæ filled with air occupying a large space in the distribution of the tissues. Their rigidity is secured by the turgescence of the parenchymatous cells, and buoyancy is much assisted by the air in the lacunæ.

The primary root is generally feebly developed, and, as a rule, does not persist through the life of the plant. Adventitious roots, however, are given off in large numbers from the various nodes of the stem. The root-hairs which are so characteristic of terrestrial roots are usually either very scanty or altogether absent. The epidermis of both root and stem is not cuticularised, but the cells remain capable of absorbing the water in which the plant is living. In the stem this tissue very frequently contains chloroplastids.

The character of the leaves differs in relation to the habitat. Those which grow in rapid streams are generally either long and thin, or are very much and finely divided, so that they offer in either case no resistance to the force of the current. In more sluggish water they are often broader, frequently attaining a considerable size. Their tissue is always very weak, the parenchyma of the mesophyll sometimes being much reduced, so that as the leaf grows old it becomes latticed, as in *Ouvarandra*. The epidermis is never cuticularised, and it contains no stomata.

In plants with floating leaves the roots and stems are similar in character to those of the first class. The leaves, however, which lie upon the top of the water are usually tough and thick, their undersides being sometimes deeply rugose. They have not the much-divided outline characteristic of submerged leaves, but are usually simple and sometimes of considerable size. Those of the *Victoria regia* are often three feet in diameter, and are turned up at the edges, forming a rim, which helps to preserve the upper surface from being wetted. The upper epidermis of such floating leaves is often either strongly cuticularised or impregnated with a waxy secretion, serving the same purpose. The leaves are consequently shiny in appearance, and water will not adhere to them. These floating leaves bear their stomata upon the upper surface only.

The petioles are long and flexible and possess a peculiar power of adapting themselves to varying depths of water. Should the stream in which they live become shallow, the leaves still remain floating, owing to the power of the petiole to become curved; should the water rise, the petioles respond by renewing their growth, so as always to keep pace with the increased depth.

Vegetative reproduction is very common, branches becoming detached from the plant, which speedily put out adventitious roots of their own, and form new plants.

From their close relation to the watery environment and their power of absorbing liquid through their general epidermis, we can easily explain the absence of the woody tissue. Their transpiration is reduced to a minimum or altogether suppressed, and there is, therefore, no need of a provision for the rapid current of water so essential to the well-being of a terrestrial plant. Their food materials reach them dissolved in the water in which they live, and hence they have no need of the complicated root system with its absorbent root-hairs, which is so characteristic of a plant growing in ordinary soil. Gaseous absorption takes place also through the general epidermis as well as from the cells of the lacunar passages.

It is noteworthy in this connection that the absence of the transpiration current is associated with a comparatively small development of the general plant body. Aquatic phanerogams are consequently never of large size.

The difference between the two groups spoken of may be well seen in such plants as *Cabomba*, which bears both submerged and floating leaves. These show respectively the characteristics described in each case.

Another class of plants which show a definite response in their structure to the conditions in which they live is that to which the so-called *xerophilous* plants belong. These are plants which grow in sandy deserts, exposed to great heat, and frequently undergoing long periods of drought. Those which are woody in habit show considerable tendency to diminish their leaf surface, probably to diminish evaporation and conserve their stock of water. Thus they often have many of their branches transformed into thorns or spines. Others which contain but little wood are succulent, and their surfaces are covered with a very thick and tough epidermis, which is strongly cuticularised. Many of them have leaves which show special absorbing structures that are often incrusted with chalk or a cake of salt. This becoming wetted by the dew gives up its captured water to the absorbing organ of the leaf, thus enabling the latter to make use of what in the absence of this mechanism would be lost to it. Many trees growing under the same conditions secrete a kind of resinous balsam, which coats the surface of their leaves and subserves a similar purpose. The water absorbed in this way is very rarely pure, but contains traces of sulphuric acid and ammonia, which, though trifling in amount, are no doubt of value in the nutritive processes. The adaptation to their environment which these plants exhibit is thus chiefly in the direction of economising a limited water supply.

The influence of the environment on the form of the plant body can be seen equally well in the case of such plants as grow in Alpine regions where the cold is usually intense, and the atmosphere for long periods so humid that transpiration is only possible at times, and where, consequently, the absorption of food materials is much impeded. The plants are generally of comparatively small size and bear thick, often rolled-up, leaves, which are evergreen. The thick exterior and the general hardness of the leaf are a response to and a defence against the cold; the rolled-up leaves bear on their protected faces abundant stomata communicating with a relatively large spongy mesophyll, so that transpiration, when possible at all, may be rapid. The evergreen leaves also are an expression of the conflict against the difficulty of the absorption of food materials, which in such atmospheric conditions is possible for only a limited period of the year. By preserving its leaves green the plant can take advantage of every opportunity afforded it.

Some lowland plants show a similar response to their environment, the form and structure of different individuals of the same species varying to a certain extent, according to their advantages or the reverse, in such conditions as sunlight or shade, drought or moisture, exposure to or protection from cold winds, &c.

Epiphytic plants show some conspicuous modifications of their structure in consequence of their peculiar habit of life. They live usually upon the surfaces of trees, to which they cling by various means, but from which they derive no nourishment except such as is afforded by accumulations of débris, &c., upon the trunks. They are not parasitic, but merely live upon the tree as many other plants grow upon rocks or cliffs. Mosses and Liverworts are very largely epiphytic, as are certain species of Phanerogams; the latter are very specialised forms and show most adaptation of form and structure. Perhaps the most remarkable feature about them is their aerial adventitious roots which are given off in some cases from every node of the stem, so that each internode has its own supply. These are often long cord-like structures which are of some thickness, often contain chloroplasts, and are either covered with a special epidermal development, or give rise to dense masses of root-hairs. In the first case, which is common among epiphytic orchids, the epidermis is many cells thick, and is known as the *velamen.* The cells are small tracheïds, with curious reticulated or spiral thickenings and often perforated. They are empty, or contain only air, and the velamen has consequently a curious glistening greenish appearance. The mass of tracheïds forms a kind of spongy covering to the root, and is capable of condensing and absorbing aqueous vapour from the moist atmosphere which usually surrounds it. The second case is illustrated by many aroids, and the dense plexus of root-hairs borne upon the aerial roots serves the same purpose as the velamen of the orchids. Besides these roots, thus adapted to absorb watery vapour from the air, epiphytes have frequently others which are closely applied to the surface of the bark on which they are growing. These are often strap-shaped, and cling very closely to the tree, absorbing from the bark the soluble products of its decomposition and any mineral débris that may be accidentally carried thither. The small amount of such food stuffs available will explain the relatively large development of the root system, which is in much greater proportion than in ordinary land plants.

Parasites are another class of plants that have undergone much modification of structure in consequence of their mode of life. The parasitic habit is seen most completely in the group of Fungi, but it is by no means confined to them. We find many cases of partial or complete parasitism among flowering plants.

The fungus which is parasitic derives all its nourishment from the plant or animal whose tissues it has invaded. Others of the same group are not parasitic, but live upon decomposing organic matter, being known as saprophytes. Their mode of nutrition is, however, essentially the same. In no case is chlorophyll present in the plant body, a fact which causes it to be unable to utilise and work up the food materials which green plants absorb from the air. Instead therefore of absorbing their carbon in the form of carbon dioxide, these fungi must take it in the form of an organic compound of some complexity, which is usually some form of sugar. Their nitrogen can be absorbed much as that of a green plant, but they appear to utilise compounds of ammonia in preference to nitrates. No doubt their protoplasm is ultimately fed with the same materials as is that of the higher plants, but they lack a great deal of the constructive power of the latter.

Associated with the absence of the constructive processes which depend upon the presence of chlorophyll we have a great degradation of the plant structure. Their body is usually composed chiefly of delicate hyphæ, which ramify in the nutrient substratum, either living or dead, and which absorb elaborated products of some complexity freely by their whole surface. There is therefore no need of differentiated absorbing or conducting tissues, which are accordingly not developed. A further consequence of the ease with which they obtain their food is the readiness with which vegetative and asexual reproduction is brought about; hence sexuality in many cases is non-existent among them.

Phanerogams which are completely parasitic show a similar degradation of structure. They possess no chloroplasts, their leaves are absent or reduced to the condition of scales, while their stems are often thick and succulent. Their roots are the so-called *haustoria*, which penetrate into the tissues of their hosts and often complete fusion of the tissue of the host and the parasite takes place. Such parasites are represented in the British flora by the *Cuscutas* and the *Orobanchaceæ*.

Many of the plants belonging to the *Santalaceæ* and the *Scrophulariaceæ* show a partial parasitism of this kind. They have short stems bearing green functional leaves, but in addition their roots become attached by curious sucker-like bodies to the roots of other plants growing near them, and from these suckers absorbing cells are developed which penetrate into the substance of the hosts and draw nourishment from them. The Mistletoe behaves similarly, striking its haustoria into the tissue of the branches of the Apple, Oak, Poplar, &c.; but here the parasitism is partly compensated by the fact that its leaves remain green when the host has lost its foliage, and by their activity they to some extent assist the tree on which the Mistletoe is growing. The relationship seems to be almost one of *symbiosis* rather than of parasitism.

The habit of capturing insects, which we have seen to be characteristic of several plants of very different forms, may also be looked upon as connected with their environment. Many of them, as Drosera, grow upon a substratum largely composed of Sphagnum plants, which yield to them a very limited supply of nitrogenous matter; others are found growing on the surface of rocky mountains, into the chinks of the stones of which their roots penetrate; others again flourish in the sandy soil of deserts; in all of which situations compounds of nitrogen exist only in very small amount. The organic substances yielded by the decomposing bodies of the captured insects may therefore form a valuable supplement to the ordinary sources of nitrogen.

Besides these influences of the environment, which are very far-reaching, and modify very largely the shape and structure of the plants exposed to them, ordinary terrestrial plants also show great power of reacting to the different external conditions which they meet. These will be considered in subsequent chapters.

CHAPTER XIV.

THE RELATION OF THE PLANT TO ITS ENVIRONMENT. IRRITABILITY.

We have seen in the last chapter that the peculiarities of form and structure which different plants present are to be associated with the character of their environment. From such facts as were there discussed it is evident that the plant is capable of receiving impressions from without, and responding to them in various ways. If we examine any plant which does not show such marked adaptation to its surroundings, we can find evidence of the possession of a similar power of appreciating differences in its external conditions, and of responding to them in various ways. Thus when certain zoospores of some of the lower Algæ, which swim freely in water, are suddenly exposed to a brilliant light, they at once take up a definite position with regard to it. When a leaf of *Mimosa pudica*, the so-called *sensitive plant*, is roughly handled, it falls from its normal position and takes up a new one, while its leaflets become folded together; when a filament of *Mesocarpus* is exposed to an electric shock sent through the water in which it is floating, it is found not infrequently that it splits up into its constituent cells. This power of receiving impressions from without is inherent in the protoplasm, and spoken of under the general term *irritability*.

Not only does it depend upon the protoplasm, but the latter must be in a healthy condition to manifest it. This healthy condition is only possible when the reactions between the plant and its surroundings or environment are properly adjusted. The environment is said accordingly to exert a *tonic* influence on the organism. The condition known as tone, which is the expression of a perfect adjustment of all such relations, is what we know as *health*. It is usual to discriminate between the different influences that may affect a plant, such as light, temperature, moisture, &c., and to speak of the proper adjustment of each of these under the names of *phototonus*, *thermotonus*, and so on. If any one of these influences changes, the plant makes an effort to accommodate itself to such change. Any interference with the condition of tone in which a plant may be with regard to a particular influence constitutes a stimulus, and leads to a response which may take different forms according to the circumstances of the stimulation. We may consequently speak of the stimulating influence of light, temperature, &c., meaning generally any change in such influences affecting a particular plant.

It is only when a satisfactory condition of tone is possessed by a plant that it can manifest its irritability. There is, however, a considerable range, for stimulation can be received and responded to when tone is far from perfect. This is particularly the case with the influence of light and the condition of phototonus. In this condition plants respond in various ways to alterations not only in light but in other features of their environment.

If we consider the nature of the environment in the case of ordinary terrestrial plants, we find it usually as follows: the root system is imbedded in the soil, among the particles of which the young root-branches ramify, and to them the root-hairs become firmly attached; the stem rises vertically into the air and bears its branches and leaves; the latter are consequently surrounded by air containing a varying amount of aqueous vapour. The aerial portion is subjected to the alternation of day and night, and during these it meets with considerable variations of temperature as well as moisture; the whole plant is constantly acted upon by the force of gravity. The subterranean parts also find considerable differences from time to time in the temperature of the soil, the amount of moisture which it contains, and the scanty amount of light which penetrates into the crevices between its particles. The environment, though to a certain extent constant, is nevertheless continually varying in these respects. Particular plants are also subject to other disturbances which are more special in their nature.

In considering the ways in which these various factors influence the behaviour of plants, we may study first their general relations to light of varying intensity, reaching them equally on all sides. We find many degrees of illumination, attaining in some cases an exceptional brilliance, as when a plant is exposed to the rays of a tropical sun. On the other hand we find cases where a plant is growing in almost total darkness.

If we consider first the latter case, we find such a plant much modified in form and structure. The stem is usually very much elongated and remains slender; it is more succulent than the normal one, and bears extremely small leaves which grow out from it at a more acute angle than those which it bears when light has access to it. In cases where the stem is normally very small and the leaves are large and broad, the change in form is different. The stem is but little changed, but the leaves become much elongated and narrow. Certain phylloclades, such as those of some of the *Cacti*, become elongated and slender instead of being broad and leaflike. The structure, too, is modified; the woody and sclerenchymatous elements are much reduced, and the parenchyma of the cortex is increased in bulk. It becomes more succulent, and the reaction of its sap is much more acid. The chloroplasts do not become green, the pigment which they contain, known as *etiolin*, being a pale yellow. In the leaves the differentiation of the mesophyll into palisade and spongy parenchyma does not take place. The parenchymatous cells of the ground tissue of the stem usually become considerably elongated; they have, indeed, grown much more than when the plant receives the normal amount of illumination. Plants thus affected by darkness are said to be *etiolated*.

That these changes are to be attributed to the absence of the light can be seen by comparing two similar plants, the first cultivated in darkness and the second under ordinary conditions of illumination, the other conditions being kept the same for both.

The explanation of the changes is somewhat difficult. The absence of light is clearly the cause of the different colour, for we have seen that, under such conditions, the pigment chlorophyll is not formed, but is replaced by the yellow etiolin. When an etiolated plant is exposed to light, the etiolin is shortly replaced by chlorophyll and the plant becomes green. Etiolin appears, indeed, to be the antecedent of chlorophyll. The question of the non-development of the woody elements and the generally increased succulence is more difficult to explain, and many hypotheses have been advanced to account for it. There is a change in the metabolism, evidently, as shown by the greater production of organic acids, to the osmotic properties of which the increased succulence is partly due. The reason for this change of metabolism is, however, not explained. Diminished transpiration may, perhaps, account for a good deal, for, as we have seen, in the absence of light there is but little output of watery vapour.

It is significant in this connection that the parts which show the excessive growth are in all cases those in which the water accumulates as transpiration becomes checked. The effect must, however, ultimately depend upon the protoplasm, which we have seen regulates all these functions, and which is profoundly susceptible to the influence of the altered conditions.

If we now examine the effects of too brilliant an illumination, we find other changes taking place. Many plants which normally have their leaves so arranged as to expose their upper surfaces to the incident rays are found under bright sunlight to place them so that their edges and not their surfaces receive the light. This phenomenon has been called *Paraheliotropism*. The effect is to preserve the chlorophyll from the destruction which follows upon too bright an illumination.

Another phenomenon, having for its purpose the protection of the chlorophyll, can be seen in many ordinary dorsiventral leaves. When brilliantly illuminated they are of a lighter green colour than when shaded, and this is found to be due to a different arrangement of the chloroplasts in the two cases. In the leaf exposed to diffused light these are collected on the upper and lower walls of the superficial cells, and they present their broader surfaces to the incident rays. When the light is cut off altogether for a considerable time and other conditions are unfavourable, they collect on the lateral and lower walls. In the illuminated leaf they are found to have partially rotated so as to present their edges instead of their surfaces to the light, and to have collected upon the lateral walls. In the first case the chloroplasts lie parallel to the surface of the organ; in the last they are at right angles to the surface. These two conditions are known as *epistrophe* and *apostrophe* respectively. When the conditions of the incidence of the light are altered, the chloroplasts change their positions accordingly. We see in these phenomena a power of the protoplasm to respond to an increase of illumination in such a way as to protect the plant from injurious consequences.

The effect of light upon structure also can be noted in the case of such leaves as are brightly illuminated; the palisade parenchyma being much more fully developed than in leaves which have grown in the shade. Indeed, the differentiation of the mesophyll into palisade and spongy parenchyma may be traced to the difference of illumination which the two faces receive, for when both are equally well lighted the palisade parenchyma appears on both sides, while some etiolated leaves, as we have seen, do not develop this tissue at all.

From a general consideration of the facts briefly summarised above we may come to the conclusion that light tends to retard growth in length. This is definitely borne out by actual measurements of growing organs which have been simultaneously cultivated under the two conditions of light and darkness. This action of light is sometimes spoken of as a 'paratonic' influence. It has been further ascertained that the rays of the spectrum which exercise this influence are those of high refrangibility, the blue and violet. To these rays the protoplasm seems to be excessively sensitive. No mere physical explanation, such as a dependence on turgidity, or change in mode of nutrition, is sufficient to account for the facts observed; they can only be referred to the power of the protoplasm to respond to the influence of the environment.

Rhythmic differences in the intensity of the illumination to which a plant is exposed, in some cases, exercise a very powerful influence on the behaviour of its leaves. This is best seen in those plants whose leaves assume different positions during the day and the night. The sensitiveness to the alternation of light and darkness is not confined to ordinary foliage leaves, but in many cases is shared by cotyledons also. The degree of sensitiveness varies greatly in different plants.

This form of irritability is manifested in a very great degree by many of the Leguminosæ. *Mimosa pudica* is perhaps the most noteworthy of them all. When this plant is removed from light to darkness its leaflets close; on being restored to light they open again, but little time intervening before the change of position is assumed in either case. Another very good instance is afforded by *Desmodium gyrans*, the so-called *telegraph plant*. During the day its leaves are extended almost at right angles to the stem (*fig.* 1241 A); as night draws on the terminal leaflets droop until they assume a position almost or quite parallel to the stem (*fig.* 1241 B). Many others assume still more curious positions, in some cases becoming twisted on their petioles or folded together in various ways. In some, as in *Nicotiana glauca* (*fig.* 1242), they rise instead of falling, and become somewhat closely approximated to each other.

Fig. 1241.

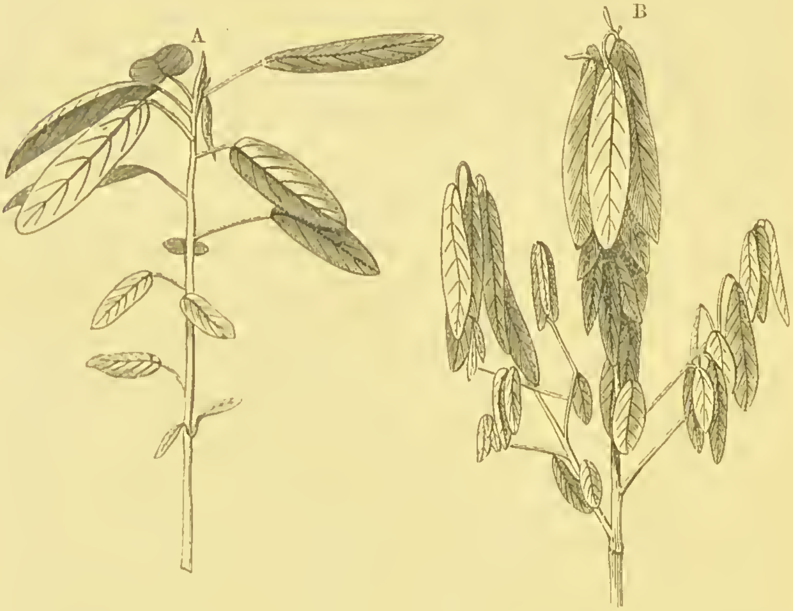


Fig. 1241. *Desmodium gyrans.* A. Stem with leaves during the day. B. A similar stem with leaves in the nocturnal position, pointing downwards. (After Darwin.)

These changes of position are generally spoken of as *nyctitropic* or sleep movements, though the latter term is misleading if it be interpreted to mean a sleep similar to that of animals. It is not difficult to prove that these curious movements are effected in response to the stimulus of the alternation of light and darkness, or to a rhythmic difference in the amount of light which they receive. When a plant which changes the position of its leaves as described is placed for a time in darkness, the periodic movement is soon very muhe interfered with, and it ultimately stops. The cessation is not, however, abrupt, but in most plants the movements will continue for at least a day. Plants, again, which are found in other countries to show this sensibility will when cultivated in England perform the movements at the normal hours and not at times corresponding to day and night in the countries from which they come. Nor is it the mere alternation of day and night; it is rather the difference between the illumination they receive during the two periods that serves as the stimulus, for some of them will not assume the nocturnal position unless they have been brilliantly illuminated during the day. The degree of sensitiveness in this case is not so great as in those where the diurnal and nocturnal positions are always regularly assumed.

Fig. 1242.

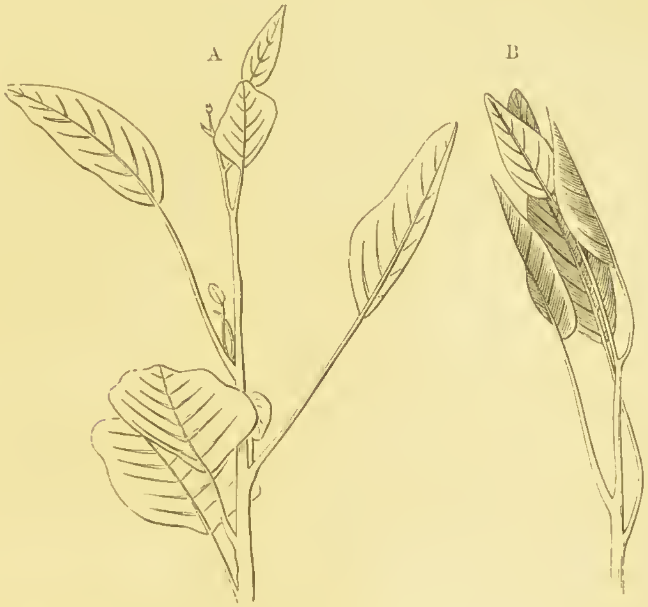


Fig. 1242. *Nicotiana glauca.* A. Shoots with leaves expanded during the day. B. The same in the nocturnal position, pointing vertically upwards. (*After Darwin.*)

The peculiar movements which the leaves perform in response to the stimulus are brought about by different mechanisms in different cases. In young leaves they are attendant upon growth, and are brought about by variations of turgescence upon the two sides of the leaf or its petiole, which are frequently followed by growth. We have seen that during growth the internal turgescence varies a good deal and leads to the curious movements of nutation or circumnutation. The actual nyctitropic movement is in these cases a modification of the extent of the circumnutation and takes place in response to the stimulus. Those leaves which show it can be seen by careful observation to be circumnutating during the day. When they assume their nocturnal position it is generally effected by their describing a much longer ellipse than during their ordinary movement. In some cases only a single ellipse is described during the twenty-four hours; in others two ellipses, the nyctitropic one being much the greater in amplitude. In yet other cases several ellipses may be described in the same time. Adult leaves which show this movement do so by virtue of a special pulvinus, or development of the hypopodium. This assumes greater turgidity alternately on its two faces, causing the leaf to droop and to rise accordingly. These leaves generally show the movement for a much longer period than those in which it is brought about by variations of turgescence followed sometimes by growth. This follows from the fact that the growth of leaves is not as a rule very prolonged.

That these movements are essentially dependent on the power of the protoplasm to receive impressions from without can be seen from a study of the conditions under which they are performed. When the soil is too dry, or when from any other cause the protoplasm in the cells is not supplied with water in sufficient quantity, they cease. When the temperature is too low they are interfered with. Violent disturbance of the protoplasm by shaking the plant will in some cases prevent their occurrence for one or two nights.

The purpose of the movement is probably to protect the delicate leaves from excessive radiation, which affects them very prejudicially. Their upper surfaces are especially liable to be injured in this way, and it is noteworthy that in all cases these surfaces are most sheltered when they take up their nocturnal positions. Often the upper surfaces of leaflets are then closely approximated together; in *Bauhinia* the leaf folds upon its midrib as an axis, so as to hide completely the ventral face.

The relation of the plant to temperature may next be considered. Plants are affected by variations in temperature in ways very similar to those depending on changes in light. In this case again we may discriminate between a *tonic* and a *stimulating* influence, though both these afford evidence of the ability of the plant to receive impressions from its environment, and to respond to them in various ways. It is not, however, always easy to ascertain the effects due to changes in temperature alone, as usually other conditions, such as light and moisture, vary at the same time as the temperature changes.

As we have seen, the environment of the plant is partly the soil and partly the atmosphere, and the temperature of both may or may not vary simultaneously. The tonic effects of differences in the aerial temperature have already been alluded to more than once in discussing the metabolic processes. There is for each of these a particular temperature at which it progresses to the greatest advantage. At lower and at higher points the protoplasm is less active, and in each case there is a point below which activity ceases, and one above which also it does not go on. The same thing is true of the processes of growth. We call these points respectively the *optimum*, the *minimum*, and the *maximum* temperatures for each function. They vary for different functions, and they vary also for the same function in different plants. We have said that this may be called a *tonic* influence, causing a more or less perfect condition of *thermotonus*; the manifestation of it is seen constantly, and it modifies not only the functions under consideration, but also the general power of the plant to appreciate all the special stimulations that it from time to time receives. We cannot say definitely how it affects the protoplasm, but the constant round of activity, chemical and physical, which constitutes its life, goes on for some reason best at the optimum temperature, and is altogether suspended at the minimum one. At the maximum temperature the death of the protoplasm generally ensues. The average points of minimum, optimum, and maximum temperature in the case of metabolism are about 10°, 30°, and 50° C., though a good deal of difference can be seen in different plants. The points observable for growth are slightly lower than those noticed for metabolism.

Variation in the temperature of the soil has a considerable influence on the absorption of water by the root-hairs, and indirectly on the process of transpiration. It has been found experimentally that warming the soil is attended by an increase in the activity of both these functions. As the absorption of water by the root-hairs is regulated by the protoplasm they contain, it is evident that this variation in activity is the expression of a form of irritability which it possesses.

An instance of the *stimulating* influence of variation in temperature is seen in the opening and closing of many flowers. Generally these are found to open in the morning and to close at night, a behaviour which is very similar to that of leaves showing nyctitropic movements. While the leaves described above respond readily to variations in the degree of illumination, flowers seem to be largely uninfluenced by these, but to respond rather to the differences in the temperature accompanying them. The variations, to be effective, must lie, however, within the range already indicated as being necessary for the manifestation of irritability at all. The response made by the floral leaves seems, as in the case of the foliage ones, to take the form of varying turgescence of the two sides of the growing part, followed in many cases by actual growth.

CHAPTER XV.

SPECIAL SENSITIVENESS AND ITS RESULTS.

Besides the general reactions of protoplasm to variations in those features of the environment which affect more or less the whole plant, we find instances of special sensitiveness in various parts to influences which are not appreciated by the whole of the living substance. Of these the most prominent are lateral light, gravity, contact with foreign bodies, and moisture. One or two other cases of special sensitiveness affecting only particular organisms may also be discussed.

Lateral Light.—The effect of the lateral incidence of light may be studied very easily in the case of young seedlings. When these are so placed that rays from a light-source illuminate one side of their stem, very soon a curvature is apparent in the part which is actively growing. This is of such a nature as to place the axis of the plant in a position parallel to the incident rays. It manifests itself sometimes very rapidly, at other times more slowly. This response to a lateral stimulation is not confined to the stems of seedlings, but may be seen to a greater or less degree in many adult plants. It is a matter of common observation that geraniums grown in a window all bend their stems towards the illuminated side.

The same stimulus may also produce in other cases the opposite effect. When a young root is exposed to it, it curves so as to place itself in the same position with regard to the incident rays, but with its growing apex placed in the opposite direction. Stems are said accordingly to grow towards, and roots away from, the light-source. This behaviour is not, however, confined to roots; it is exhibited by the tendrils of *Bignonia capreolata*, by the peduncles of *Cyclamen persicum*, and by many other organs.

Leaves in many cases show a similar sensitiveness, but the position they assume is different again. They place themselves so as to present their upper surfaces at right angles to the incident rays.

These three movements in response to the stimulus of the lateral light are spoken of as *heliotropism*, *apheliotropism*, and *diaheliotropism* respectively. The advantages thus secured are in some cases very obvious; the heliotropism of the stem places its leaves in the most favourable position for the action of the chlorophyll in decomposing the carbon dioxide they absorb; the apheliotropism of the root assists it in penetrating into the crevices of the soil. The tendrils of Bignonia are aided by it in coming into contact with a support about which they may twine, while the apheliotropism of the peduncles of Cyclamen, which are bent downwards in a hooked fashion, enables them to grow towards the soil, into which they press the capsule, thus burying the seeds.

The response to the stimulus varies sometimes with the age of the organ. The hypocotyl of the Ivy is heliotropic when young, but becomes apheliotropic when old.

The sensitiveness varies very greatly in different organs. Some of the seedlings of *Phalaris* examined by Darwin responded to such a feeble degree of illumination that it was hardly sufficient to cast the shadow of a pencil upon a piece of white paper held close behind it. The rapidity of the response also varies, some organs bending almost immediately, while others do so much more slowly. To this point we shall return later. The movement of apheliotropism is usually much slower than that of heliotropism.

The bending is not caused by a direct interference of the light with the actual growing part. It would seem at first as if the retarding effort of light upon growth might explain the bending of the organ towards the light-source, the non-illuminated side continuing to grow while the illuminated one is checked. This explanation is directly contradicted by the phenomenon of apheliotropism as exhibited by a root. It is moreover proved to be an insufficient explanation by the fact that the part which is sensitive to the stimulus is not the part which actually bends. Darwin showed this by amputating a small region about ·1 inch in length from the tip of the seedling, or by lightly covering the same part with an opaque cap, when he found that the heliotropic curvature did not take place. Further, when the part normally curving under the influence of the stimulus is mechanically hindered from bending, the curvature takes place at a part a little lower down, which normally remains straight.

When the lateral light is fairly intense, the resulting movement takes place uninterruptedly; when it is only weak, the position is assumed by a series of zigzag movements, indicating that the new movement is an exaggeration of the ordinary circumnutation of the part. When the final position is reached the organ is found to circumnutate about the new direction of the axis.

A somewhat similar response to a lateral light is exhibited by many unicellular organisms. When these are exposed to oblique illumination they take up a definite position with regard to the incident rays, placing their long axis parallel to them if the light is weak, and at right angles to them if it is intense. This behaviour is known as *Phototaxis*; it is exhibited by the zoospores of many of the Algæ and by certain Desmids.

GRAVITY.—The force of gravity exerts an influence upon plants somewhat resembling that of lateral illumination. Thus most stems grow vertically upwards into the air; primary roots grow vertically downwards into the soil. A few organs, such as certain rhizomes, the stolons of many plants, and most secondary roots, grow at right angles to the direction of gravity. When one of these is placed at an angle from the position it usually takes, a curvature of the growing region results, which lasts till the normal attitude is regained. When a young seedling is detached from the earth and laid upon its side, the stem gradually curves through an angle of 90° and becomes erect, while the young root curves in the opposite direction till it points vertically downwards. Similarly when a stolon is placed vertically, its apex is slowly deflected until it is parallel with the soil. These movements are termed *apogeotropism*, *geotropism*, and *diageotropism* respectively.

To prove these movements to be responses to the stimulus of gravity, it is necessary to eliminate the action of the latter force and to observe the direction of growth under the new conditions. This can be done by causing the plant to grow upon an apparatus known as a *Klinostat*, which is a wheel rotating upon a horizontal axis at a regular rate, a complete revolution being made in about twenty minutes. The plant is placed in a horizontal position on the revolving wheel, so that each side of the axis comes alternately under the influence of the force. All parts of it are so affected equally, and it is found that then no curvature of the horizontal axis of the plant occurs in either direction. Another experiment, due to Knight, pointing to the same conclusion, is that of growing a plant upon a rapidly revolving wheel mounted on a vertical axis. When the wheel revolves sufficiently rapidly, though the plant is exposed all the time to the action of gravity, the centrifugal force of the apparatus is so much greater than the force of gravity that the plant does not respond to the latter. Instead, it responds to the stimulus of the rapid rotation, and the roots grow outwards from the centre of the wheel, while the stem grows inwards towards it. The force acts much like that of gravity, and the plant responds to it in a similar way, the root growing in the direction of the force and the stem in one opposite to it.

As in the case of heliotropism, the part which receives or is sensitive to the stimulus is not the part which curves. In the case of a root it has been demonstrated by Darwin, and more recently by Pfeffer, that the sensitive part is the tip, while the curvature is some distance further back, where active growth is taking place.

As in the former case, the movement of geotropism or apogeotropism is not confined to growing organs. When the haulm of a grass is placed horizontally on the ground, as is the case when a patch of wheat or other grass is beaten down by wind or storm, it after a time again becomes erect. The new position is due to the renewal of growth on the under side of the swollen nodes, which is excited by the stimulus and proceeds till the stem is again vertical.

As in the case of heliotropism, the sensitiveness varies very much in different plants. The movement is usually a modification of circumnutation.

CONTACT WITH A FOREIGN BODY.—Many instances of sensitiveness to this form of stimulus have been observed. When a leaf of *Mimosa pudica* is handled, the leaflets all droop downwards with great suddenness, and if the handling is very rough all the leaves on the plant behave similarly. When a stamen of *Berberis* is touched at a point a little below the anther, the whole stamen bends forwards towards the pistil. The stigma of *Mimulus*, which is normally composed of two lobes extending outwards from each other, will, if either lobe is touched with a fine point, close, so that the upper surfaces come into contact with each other. When an insect alights on the surface of a leaf of *Drosera*, the tentacles with which it is furnished slowly curl over so that their terminal glands are brought together at the point of irritation; and at the same time the glands pour out a viscid, slightly acid secretion which is capable of digesting the proteids of the insect's body. The leaf of *Dionæa*, the Venus's fly-trap, which is normally widely expanded, closes with great rapidity when one of the six sensitive hairs which spring from its upper surface is touched. The leaf closes as if the midrib were a hinge, approximating the upper surfaces on each side so as to imprison the body which touches it.

This form of sensitiveness is peculiarly characteristic of the growing apex of young roots. If a seedling bean is taken, and a small piece of cardboard is attached to one side of the tip, a curvature speedily results which causes the root to bend away from the irritating body. If the movement takes the sensitive part away from the latter, the curvature is slight, but if, as in the experiment, the foreign body accompanies it in its displacement, the curvature will continue until the root is coiled completely round. The stimulus in the case of this movement must be prolonged, differing thus from the cases noted above, where a mere touch is sufficient to bring it about.

The cause of the curvature must be the sensitiveness of the protoplasm to the stimulus of contact. The movement cannot result from any injury done to the cells causing a hindrance to growth, for if this were the case the curvature would be towards the body touching the root, whereas it is in the opposite direction. If the cells of the side of the root at some distance from the tip are stimulated in this way, the curvature is round the stimulating body and not away from it. This may very likely be due to such a mechanical hindrance of the growth. In the first case, moreover, the part which shows the curvature is not the part irritated, but a region some little distance further back.

Perhaps the best instance of this susceptibility to slight contact is afforded by the behaviour of tendrils, the twining of these organs round their supports being altogether due to it. A very slight touch is sufficient to bring about a perceptible curvature; in the case of the tendrils of *Passiflora gracilis*, indeed, Darwin found that the contact of a small loop of thread weighing not more than $\frac{1}{32}$ grain induced it, while a mere touch caused one to assume the form of a helix in about two minutes. This is perhaps the most sensitive tendril known; with others a stronger stimulus is needed and the time taken for the response is longer, the irritability varying greatly. The behaviour of tendrils in twining is somewhat peculiar. When young they are generally circumnutating, and if in their movement they come into contact with any foreign body they begin to curve towards it. If the contact be not prolonged, the tendril will curve for some time, but will ultimately become straight again and move as before, till it touches something else. If, on the other hand, the body first touched is one round which the tendril can twine, it coils itself round it; the stimulus thus persists and the resulting curvature increases it, till the support is encircled many times by the sensitive twiner. The coiling is seldom confined to the part of the tendril in contact with the support, but the free part between the latter and the axis of the plant also twists itself into a spiral coil. If the two be not very close together, this spiral usually shows two parts, the coils of which are in opposite directions. This is, however, only because the filamentous body is attached at both ends.

The tendril, though thus sensitive to contact, does not coil, according to Darwin, if its sensitive surface is struck by drops of rain, nor in the case of the Passiflora already alluded to, if contact takes place between two tendrils.

The sensitive region varies in different tendrils, but it cannot be so strictly localised as in the case of the growing root. They are usually irritable on one side only, which is slightly concave, though in some cases the sensitiveness extends all round them. The lower part of the tendril is, as a rule, only sensitive to prolonged contact. Their susceptibility further varies with their age, being greatest when they are about three parts grown. The part which first responds to the stimulus is usually the part touched, but, as we have seen, the coiling also takes place nearer their bases, so that we have an evident transmission of the stimulus backwards, as in other cases noted. The method of response is usually increased turgidity upon the convex side followed by greater growth, though in certain cases careful measurement has shown that the concave side becomes perceptibly shorter.

This sensitiveness to contact, which is so markedly shown by tendrils, is possessed also, though to a much smaller extent, by most climbing stems, whose behaviour has already been described. It is shown, again, by the parasite *Cuscuta*, whose stem twines round those of other plants growing near its germinating seeds, and whose haustoria ultimately penetrate them. Twining petioles of similar behaviour are also met with.

Another form of irritability is exhibited by growing shoots, which is perhaps somewhat akin to sensitiveness to contact. If a shoot be struck laterally several times near its base, its apex curves over towards the side struck. If the blows be given near the apex, the curvature is in the opposite direction.

The mechanism whereby the response to the stimulus of contact is brought about in growing organs, we have seen to be an increased turgidity on the convex side, followed by growth. In those cases in which the organ is mature, it is evident that growth can have nothing to do with the movement. In these instances we have rather to do with a modification of turgescence, involving a redistribution of the water contained in the organ. The falling of the leaflets and leaves of *Mimosa* is due to a sudden change in the protoplasm of the cells in the lower side of its pulvinus, in consequence of which water escapes from them into the intercellular spaces between them. It is attended by a change of colour, the pulvinus becoming of a deeper green in consequence of the replacement of air there by water. If a leaf be cut off, and after the plant has recovered from the effects of the injury an adjacent leaf be sharply stimulated, water is seen to exude from the cut surface of the pulvinus. The cases of the irritable stamens and stigmas are probably to be explained similarly. The closing of the leaf of Dionæa is due also to a redistribution of the water in the cells, brought about by a rapid change in the protoplasm somewhat perhaps akin to contraction. In Drosera the inflexion of the tentacles has been found to be preceded by a peculiar churning movement of the protoplasm in the cells upon the side which becomes concave. This movement, which Darwin, who discovered it, called *aggregation*, is attended by a loss of turgidity.

Moisture.—Sensibility to variations in the moisture of the environment is not so widely distributed as are the forms of irritability hitherto discussed. It is exhibited chiefly by roots and by the rhizoids of the *Hepaticeæ* among green plants, and by the hyphæ of certain *Fungi*. These tend to curve in the direction of a moist surface if they are growing near one. When young seedlings are cultivated in a vessel which contains moist sawdust or sand, and is perforated so as to allow the rootlets to protrude, these grow vertically downwards, according to their geotropism. As soon as they protrude, they curve to a greater or less extent towards the moist surface, as if seeking the moisture. This phenomenon is known as *hydrotropism*. The root-tip, as in other cases, is the sensitive part, while the curvature takes place further back, where growth is most active. Negative hydrotropism is very rare, being exhibited only by some of the *Myxomycetes*, which move away from moisture.

The advantage of this form of sensibility is evident in the case of the root, which, by virtue of it, is drawn towards the moisture of the soil as it penetrates between its particles.

A curious instance of appreciation of lack of moisture is afforded by *Porlieria hygrometrica*, which under such conditions closes its leaflets much as nyctitropic plants do when light gives place to darkness.

CHEMICAL STIMULI.—Besides the forms of sensitiveness which we have discussed so far, there is evidence that vegetable protoplasm can appreciate stimuli of a different kind. These are less widely manifested, but instances are fairly abundant among the lower forms of plants.

A certain number of unicellular organisms are strongly affected by the presence of free oxygen. The most interesting case of this is that of *Bacterium termo*; when a number of these plants are placed in a drop of water on a slide, and examined under the microscope, they are found to aggregate at the edges of the cover-slip. If a small green Alga is placed in the drop with them and the slide exposed to light of a sufficient intensity to enable the decomposition of carbon dioxide to take place, the evolution of oxygen attracts the bacteria, which at once swarm round the alga. So sensitive are they to this attraction, that if the spectrum of sunlight is thrown upon the alga, the bacteria accumulate at those parts which are illuminated by the red and blue rays, the rays which we have seen to be capable of effecting the decomposition of the carbon dioxide. This response to the attraction of oxygen is not confined to these bacteria; it is afforded by many zoospores, and also by the plasmodia of some of the *Myxomycetes*.

It has already been observed that when the necks of the archegonia of the Cryptogams open they discharge a certain mucilaginous fluid which attracts to the organ the free-swimming antherozoids. Careful experiments have been made in many cases to ascertain what is the nature of the attraction, and it has been found that the mucilage contains various substances which the antherozoids seek. In the case of the *Ferns*, and some *Selaginellas*, it has been determined that the attractive body is malic acid. When a capillary tube containing a weak solution of this substance is inserted into water containing some of the antherozoids, they make their way very quickly to the orifice of the tube. In the case of *Mosses* the attractive substance is cane sugar. That there is a definite attraction appears from the fact that strong solutions of either acids or alkalies are avoided by them with equal earnestness.

A similar behaviour marks the plasmodia of certain of the *Myxomycetes*. They move slowly towards a watery extract of tan, but retreat from a solution of sugar, glycerine, or certain neutral salts. Similarly, the zoospores of *Saprolegnia* are attracted by a solution of extract of meat.

The sensitive tentacles of *Drosera* can respond not only to contact, as before mentioned, but also to various substances placed upon the leaf. They are easily induced to bend by drops of liquid containing proteid matter, such as solution of albumin, or milk. Certain inorganic salts, notably carbonate of ammonia, produce the same effect.

A curious instance of this kind has been noted recently by Miyoshi. He cultivated certain fungi in gelatin containing a small proportion of sugar. Under the stratum in which the hyphæ were ramifying he placed another containing a larger proportion of sugar, and between the two arranged a membrane. The hyphæ very soon grew towards the stronger sugar solution, and to reach it penetrated the membrane.

Other instances of similar behaviour might be quoted. To this form of sensitiveness the name of *Chemotaxis* has been given.

CHAPTER XVI.

THE NERVOUS MECHANISM OF PLANTS.

It is difficult to refrain from coming to the conclusion, from a consideration of the facts examined above, that the nervous system of the animal kingdom is represented in the vegetable one. That plants are sensitive to variations in the conditions surrounding them, and that the responses they make to such variations are purposeful, and conduce to the wellbeing of the organism, is abundantly evident. The response to any external stimulus, moreover, has been seen to be dependent upon the plant being in a state of health and vigour. If its wellbeing has been interfered with by such disturbances as deprivation of light, or lack of oxygen, or exposure to too high or too low a temperature, no response is given, for its irritability is in abeyance or destroyed. Its own age again has been seen to have an important influence upon its power of receiving impressions and its behaviour in responding to them.

In considering from this point of view the way in which plants are affected by external influences, it is noteworthy that an exceedingly small stimulus is able to bring about a very considerable effect, and that there is no direct ratio between the intensity of the stimulus and the resulting movement. The tendrils of Passiflora, already alluded to, are caused to move by the contact with them of a small piece of thread, weighing not more than $\frac{1}{32}$ of a grain, and the resulting movement is of considerable extent and is prolonged for some time. The sensitive hair of the leaf of Dionæa needs only a touch to cause a rapid movement of the whole leaf-blade; the pricking of the staminal filament of Berberis causes a considerable movement of a relatively bulky body. The seedlings of Phalaris bend with some speed towards a light which is not sufficient to cause a visible shadow at the distance at which they are placed from it.

It can hardly be imagined that such slight disturbances can act mechanically upon the parts that move. This point is illustrated by the observation made by Wiesner, that if a part which responds only to the stimulus of lateral light be exposed for some time to such an illumination, and then, before the curvature has begun, be removed into darkness, it will slowly bend towards the side which has been stimulated. The same observation has been made by other observers in the case of the stimulus of gravity. There is no other explanation possible than that the stimulus brings about changes in the protoplasm of the cells of the moving part which slowly modify their relation to the water of their contents so that a great alteration of their turgidity results. Moreover the separation of the part stimulated and the cells which are the seat of the resulting action implies that there must be in the plant a means of rapidly conducting such external impressions from one part to another. To this point we shall return.

If then we admit that there is even a rudimentary nervous system in plants, we should expect to find a more or less evident differentiation of it in the direction of sense organs. This is in fact afforded in many cases. Darwin found that the seedlings of Phalaris were not sensitive to the faint light employed in his experiments except at a small region extending about $\frac{1}{10}$ inch from the apex. If this part were covered by an opaque screen in the shape of a small blackened cap, of not sufficient weight to cause any flexion of the stem, the seedlings no longer bent towards the light. Similar careful experiments made by the same observer pointed out that the tip of the young root was its only sensitive part. Other observers have proved the same thing. Cisielski amputated the tips of certain rootlets and laid them horizontally on a support. They then did not show any sensitiveness until they had recovered from the wound and a new root-tip was formed on each. As soon as the new tip was developed the rootlets showed a power of reacting to the force of gravity, and the curvature resulted in the usual place. More recently Pfeffer has demonstrated the same localisation. The whole leaf of Dionæa may be somewhat roughly handled without closing, so long as no contact is made with the hairs upon a particular portion of the blade. But so soon as one of these is touched the leaf closes. It is impossible to avoid the conclusion that we have to do here with a localisation of sensitiveness or the differentiation of sense organs. True the differentiation is anatomically very slight, but physiologically it is considerable. The same sense organ again is sensitive in very different degrees to different stimuli, and, as we should expect, to different strengths of the same stimulus. If a sensitive organ be acted upon at the same time by two stimuli which usually produce opposite movements, the resulting position is always that which would be caused by the stronger of the two.

One of the characteristic features of the nervous mechanism of an animal is the definite character of the response made to a stimulus. This point is also brought out in considering the behaviour of the parts under notice. If a root-tip is brought into contact with an obstacle, the bending is invariably in such a direction as to enable the root to pass it. When one is allowed to impinge upon a plate at right angles to its direction of growth, the curvature continues till the root has turned through a right angle and can grow parallel to the opposing surface. If on the other hand a part some little distance above the tip is obstructed, the curvature is towards the obstacle, a course which serves the same purpose. The stimulus causing the movement of hydrotropism serves to bring the root-hairs into contact with the moist surface, thus enabling them to discharge their appropriate function. The behaviour of the tentacles of Drosera is very interesting in this connection. The leaf is of some size, and can therefore receive stimuli over a fairly large area. When the tentacles bend over in response to the alighting of an insect, they do not do so irregularly, but always place their glandular apices directly upon the spot which is the centre of the disturbance. This is very definitely purposeful, the invader being captured and digested wherever it alights, as all the tentacles are brought to bear upon it. The purposeful character of heliotropic and diaheliotropic curvatures is also very evident, the leaves being always placed thereby in the most favourable position for the discharge of their functions.

This special sensitiveness can be distinguished again from the general state of irritability in the plant. So long as the conditions remain favourable the latter is considerably prolonged, but the power of responding to particular impressions disappears much sooner. In some cases this power can be ascertained to have been lost by an organ while it still retains its power of circumnutating. The effect of a prolonged stimulation sometimes is to fail to produce a movement. Thus in the case of Dionæa, repeated touching of one of the hairs, if the leaf be prevented from closing, ultimately leads to such a touch having no effect when the leaf is released. This is a result of exhaustion or fatigue. At first it may seem doubtful whether or no the interference with the free response of the leaf may have so injured the motor mechanism as to make it incapable of acting. The exhaustion, however, is shown to be that of the hair and not of the hinge, by the fact that touching another of the hairs at once causes closure.

The nervous sensitiveness is by this and many other similar experiments shown to be capable of fatigue. A similar suspension of power may be demonstrated by exposing the sensitive parts to anæsthetics, such as the vapour of chloroform, ether, &c. The effect of these drugs at once suggests a similar action to that which they have on the nervous mechanism of an animal. When the effect of the fatigue or the anæsthetic has passed off, the organ again becomes capable of responding.

A nervous system generally can be shown to possess three distinct parts: one means whereby external stimulation is received and appreciated; another whereby movements, &c., are caused;

and a regulating and controlling part which can co-ordinate the response to stimulation, or can initiate movements, &c., in its absence. In the higher animals these are well differentiated from each other; we have the sense organs and the afferent nerves; the efferent nerves, connected with the motor and other mechanisms; and the nerve-cells which possess the co-ordinating power. In the much less differentiated plant-body the first two of these at least are recognisable. If we compare the sense organs of the animal with the sensitive parts of the plant, we find a certain correspondence, though it must not be pressed too far. The power of sight is very complete in the higher animals, in consequence of the highly differentiated character of the eye. In the lower animals it becomes less and less perfect, till in some it goes probably little further than the power of appreciating light. This power we have seen to be possessed by certain parts of the young seedlings of various plants in a very high degree, and by other organs to a less extent. The sense of touch may be compared with the power of responding to the stimulus of contact shown by tendrils and by the tips of roots; the muscular sense, or power of appreciating weight, is not dissimilar to the property of responding to the force of gravity, while the chemotactic behaviour of the organisms described above suggests a rudimentary power of taste or smell, or both.

FIG. 1243.

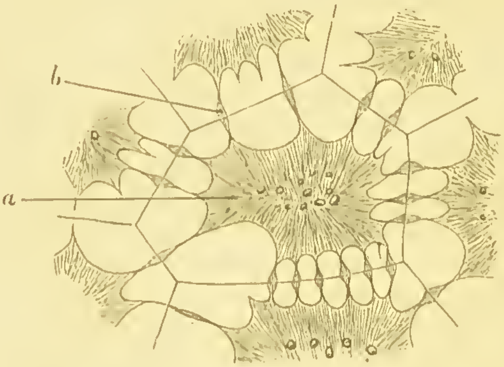


Fig. 1243. Continuity of the protoplasm of contiguous cells of the endosperm of a Palm seed (*Bentinckia*). *a.* Contracted protoplasm of a cell. *b.* A group of delicate protoplasmic fibrils passing through a pit in the cell-wall. (Highly magnified, after Gardiner.)

The conduction of the impulses received is due in animals to the existence of differentiated nerves. The way in which it is carried out in plants has been much debated, but since the discovery of the continuity of the protoplasm through the cell-walls, there is little doubt that we have here a similar mechanism. There is scarcely any differentiation, but the power of the protoplasm to conduct disturbances from one part of the cell to another is a matter of common observation. The connecting strands between adjacent cells (*fig.* 1243) will suffice to suggest how impulses from the tip of the root may reach the growing cells.

The motor mechanism seems at first to be entirely different from that of the animal organism. Closer consideration, however, lessens the difference considerably. The contractile power is but little developed in vegetable protoplasm, but it has its representative in the power of resisting or assisting the transit of water. The effect is really similar in both cases; in the one the disturbance to the protoplasm leads to a contraction of its substance, in the other to its modifying its resistance to the passage of water through it. Each protoplasm responds in its own appropriate fashion.

The plant shows, however, an almost complete absence of the differentiation that reaches its highest point in the nerve-cell. There is apparently no co-ordinating mechanism which receives the impulses from the sense organs, and initiates in consequence the resulting movement. This need not, however, lead us to deny the existence of a nervous system, but only to remark upon the very slight degree to which it is differentiated. Darwin has called attention to one instance in which something of the kind is seen. When a tentacle of Drosera is stimulated, the actual bending is preceded by a curious motility of the protoplasm of the cells of its stalk which has been called *aggregation*. If a tentacle on the leaf is excited, the tentacles of the margin are gradually inflected towards the excited spot, as already described. If the cells of one of the marginal tentacles are watched during the experiment, their contents are found to undergo this aggregation, but those nearest its apex manifest it first. If the aggregation were the *direct* effect of the stimulus, those which it reached first, *i.e.* those nearest the base, would respond first. The stimulus, apparently, has to travel up the tentacle to the gland, and a disturbance must originate there in response, this disturbance travelling down the tentacle in the direction of its base. Darwin has pointed out that this corresponds in a measure to the reflex action of the animal organism.

If we are able from these considerations to recognise in the plant a nervous system in any way comparable to that of the higher animals, we are led to the view that the differences between the two are to be referred to differences of degree of differentiation. The latter is on the whole very slight in plants, nothing at all corresponding to the powers of consciousness or volition. There is, however, a differentiation in the sense organs in the direction of sensitiveness, which will equal if not surpass the powers of those of an animal. The tendril of Passiflora appreciates and responds to a pressure which cannot be detected by even the tongue; the seedlings of Phalaris readily obey the stimulus of an amount of light which is hardly perceptible by the human eye. The power of response to the stimulus is of course very much less than in the animal, but this, as we have seen, depends upon the differences in the motor mechanisms. In the vegetable protoplasm we have a much slower response, as well as one of a different kind, the effects taking as a rule longer to manifest themselves, and lasting for a longer time after the stimulus has been withdrawn. We have, however, as in the animal mechanism, a much better response to a cumulative or prolonged stimulation than to one which is rapid and transitory.

CHAPTER XVII.

AUTOMATISM. RHYTHM.

The instances of sensibility we have been considering have been seen to be such as are manifested in response to external stimulation of various kinds. The responses made have been found usually to take the form of what are generally called movements of either the whole plant or of some of its members. Though called movements, however, they must not be interpreted in all cases to be such in the strict sense. They are rather changes of position brought about by varying turgescence, or alteration of the rate of growth in particular aggregations of cells. The protoplasm has been seen in many instances to play rather a passive than an active part in bringing about the change in position.

Besides these, however, we have yet to consider some similar phenomena in which the protoplasm is more directly concerned, and the nature of the stimulation, or the exciting cause of the changes involved, is very obscure. Such phenomena are roughly classed together under the name of *automatism*, or *automatic movement*.

We have seen that certain plants at particular times emit from their body small masses of naked protoplasm which are furnished with a varying number of long filaments. These filaments, which are protoplasmic, are ordinarily in a state of active vibration, causing currents in the water in which they live, which float them quickly from place to place. Such free-swimming cells include the zoospores of the Algæ and the antherozoids of these and higher plants. The movement is brought about in the absence of any external stimulation, though the cells are capable of receiving such impulses. The cause of the movement is probably the contraction of each side of the filament, or *cilium*, alternately, or of the part of the cell just at its point of attachment. The impulse leading to the movement must be sought in some decomposition originating in the protoplasm itself, and not excited by any stimulus from without. The phenomenon is often spoken of as *ciliary motion*.

Of a somewhat similar character is the curious creeping movement of the Myxomycetous fungi. Each of the zoospores of these organisms consists of a mass of naked protoplasm which makes its way over the surface of its substratum by putting out blunt processes of its own substance, known as *pseudopodia*. These are protrusions of the ectoplasm, and the more fluid endoplasm is in some way drawn into them, so that the rest of the cell follows the movement of the pseudopodium. Which part of the operation really corresponds to the act of contraction is disputed, but it seems probable that it is the second, and that the first protrusion is of the nature rather of relaxation. In either case, however, the movement is independent of any external stimulation.

The *Diatoms*, which we have seen to form a sub-class of the Algæ, are capable of a curious gliding movement, which enables them to make their way with some rapidity through the water in which they live; they also are found to do this in the absence of any apparent stimulus; the *Oscillatoriæ*, which are filamentous algæ anchored to a substratum by one end of the filament, are also in constant wavy motion to and fro: a movement the mechanism of which is still unexplained, and which possibly resembles that of the diatoms. These are instances of the same automatism, the protoplasm in all probability originating the movement and carrying it out.

In certain lowly-organisms such as *Chlamydomonas* there is to be seen in the protoplasm a clear space or vacuole, which exhibits a more or less regular pulsation, appearing slowly as a nearly spherical cavity, and then suddenly disappearing, recalling the active contraction of animal protoplasm. These, like the last-mentioned plants, are instances of movement in consequence of internal changes and not of external stimulation.

In the higher plants evidence of this special automatism is not lacking. Setting aside what is common to all plants, the inherent power of living substance to construct itself from food materials, to carry on respiration and other vital functions, which are of course evidence of automatism, we have in a few cases distinct power of automatic movement. The protoplasm of the cells of the leaves of *Vallisneria*, of the internodal cells of *Chara*, of the pollen-tubes of many plants, of the cells of the staminal hairs of *Tradescantia*, and others quoted in discussing the structure of the cell, is in constant rotation round the cell, or movement within it in definite directions.

FIG. 1244.

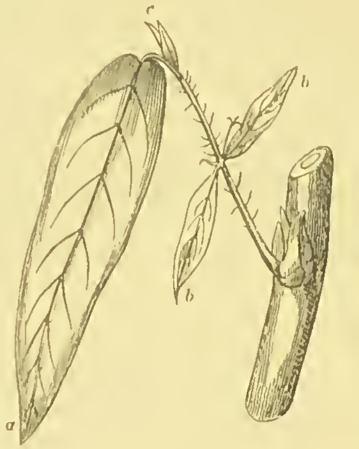


Fig. 1244. A portion of a branch, with a leaf, of *Desmodium gyrans*. The leaf, which is compound, consists of a large terminal leaflet, *a*, and two smaller lateral ones, *b*, *b* There are also two other rudimentary leaflets, marked *c*, near the terminal leaflet.

These instances impress upon us the belief that all protoplasm is the seat of active molecular movement, the intensity or vigour, however, varying very greatly in different cases. Indeed the life of the protoplasm is intimately bound up with such a motile condition. Manifestations of this motility have from time to time been noticed above ; especially we may again allude to the regulation of turgescence, which we have seen to be one of the properties of vegetable living substance.

In many cases it can be noticed that these automatic movements set in with a certain definite intermittence, recurring, so long as conditions are constant, at regular intervals. The pulsating vacuoles already alluded to may be instanced in this connection. Such regularly intermittent actions may be described as *rhythmic* and the intermittence spoken of as rhythm.

When we look back upon the various functions we have examined we find evidence in them that rhythmic changes in the protoplasm are very widely met with in the life of the vegetable organism. Very conspicuous instances of it are afforded by certain movements often exhibited by the leaves of particular plants. Perhaps the most familiar of these is the so-called *telegraph* plant, *Desmodium gyrans.* The leaves are ternate, the terminal leaflet being very large in comparison with the two lateral ones (*fig.* 1244). If the plant be watched while exposed to a suitable temperature, the lateral leaflets are found to move up and down on the rachis, sometimes passing through an angle of 180°, and twisting slightly as they move. They thus describe a kind of ellipse, the duration of the movement being about two minutes. Many other instances of a similar kind are known, the Leguminosæ furnishing many examples. All of them do not exhibit them with the same ease, as they are much interfered with by the changes in position caused by external stimulation. They can often be made evident by keeping the plant either in the dark, or exposed to light of uniform intensity. Darkness, however, if too prolonged, results in the cessation of the movements, as these can only take place while the plants are in a condition of phototonus. The mechanism of the movement in most of these cases is the varying turgescence of pulvini at the bases of the leaflets. The alterations in this turgescence are the expression of rhythmic changes in the protoplasm of the cells.

The same rhythmic changes have place in all young growing organs, leading to the variations in turgidity that cause the movements of nutation and circumnutation which accompany growth.

The nyctitropic movements we have discussed may be quoted in support of the existence of rhythm. Though they are ordinarily exhibited in response to the stimulus of alternate periods of light and darkness. many plants continue to exhibit them when altogether removed from light. That they cease after a day or two of darkness, is probably due to the fact that the plants are then no longer in a phototonic condition. Many flowers continue to open and close their corollas when removed from variable to constant conditions.

The same tendency to rhythmic change is shown in what is called the *periodicity* of the various vital functions. If, for instance. the root-pressure of a plant be examined by the aid of the apparatus already described, in which the water taken up is made to support a column of mercury in a manometer, when the column of mercury has reached what we may call its *mean* or *average* height, it does not remain there, but begins to oscillate. It rises in the morning till about midday, then sinks somewhat, rises again towards the evening, and falls during the night. There is thus roughly a daily variation of the absorbent activity of the roots, which is very little affected by changes in the environment; it is in fact *automatic*.

There is a similar daily variation in the bulk of a plant, the diameter of the various organs diminishing from night till some time in the afternoon, and increasing thenceforward till dawn. These variations largely depend upon the distribution of the water which the plant contains, which is regulated by the living substance.

Many other instances of the same periodicity or rhythm might be quoted, but it is hardly necessary to multiply examples.

Though this rhythmic alteration of the protoplasm in various ways is no doubt inherent in plants, as appears from its occurrence when conditions are kept constant, it is easily affected by external causes. The effect of continuous darkness, we have already seen, is that the movements are made irregular and ultimately stop. In many cases the difference in degree of illumination between day and night affects the readiness with which the nyctitropic movements of the leaves are brought about. After brilliant sunshine they set in more quickly than after a dull light.

These movements may indeed show an artificially induced rhythm, superposed upon a normal one, in the same way as the movements of heliotropism, geotropism, &c., have been seen to be based upon the ordinary movement of circumnutation, to be, indeed, an exaggeration of it. In some cases the tendency to rhythmic change can be manifested by the production of an altogether artificial rhythm, induced by submitting the plant to intermittent stimulation. Darwin and Pertz have described a very interesting experiment of this nature. A plant was fixed to a spindle placed horizontally, which, by an arrangement of clockwork, was made to make a semi-revolution at intervals of thirty minutes. The force of gravity thus exerted its effect on alternate sides for this interval of time, so that each side of the stem tended to become convex apogeotropically in turn. After a period of exposure upon the instrument the clockwork was stopped. Instead of the side which was then undermost increasing its convexity till the stem was vertical, the two sides continued to become alternately convex, as if the reversal of the instrument was still taking place. There was, in fact, an artificially induced rhythm manifested.

The conflict between the natural rhythm and the movement due to stimulation can be observed in the heliotropic curvature of many organs. The heliotropic position is not brought about by a direct movement of the organ, but by its describing a series of ellipses. The organ at the time of the incidence of the light stimulus is performing its ordinary circumnutation, the apex describing a circle. The effect of the stimulus is to turn that circle into an ellipse ; when the rhythmic impulse coincides with the stimulus of the light the movement is accelerated, and the resulting curve takes the direction of the long axis of the ellipse ; when the two act in the opposite direction to each other, the short curve of the same figure is described. The same result is obtained under the stimulus of geotropism.

The slow response to the action of a stimulating force may frequently be explained in the same way. Often, however, the long delay in responding is due to the sluggish nature of the protoplasm, a considerable time being taken up in inducing the necessary change in its motility. We have then what is called a *latent period*, before the manifestation of the irritability. Similarly the results of the stimulation continue for some time after the exciting cause is removed, giving what is called an *after effect*. An example of this is afforded by some experiments of Cisielski's ; he laid some geotropic roots horizontally on moist sand, and allowed them to remain there for some time. Before they began to show their geotropic curvature, he amputated the tips, which we have seen to be the sensitive parts or sense organs. After a time the geotropic curvature nevertheless took place. The stimulus was received while the roots were intact, but its manifestation in the form of curvature took place as an after effect, even after the stimulus had altogether ceased to act.

CHAPTER XVIII.

REPRODUCTION.

THE phenomena we have hitherto been considering all concern the life of the individual plant. As this, however, at the best is comparatively limited, we find plants endued with the power of giving rise to new individuals. The process of originating each new individual from its parent or parents is known as reproduction.

We have already seen that this process may be brought about in one of three ways. In the simplest cases, in what is known as *vegetative* reproduction, no special cell is produced for the purpose, but some part of the parent becomes detached and grows into the new individual at once. We see this easily in the reproduction of the lower Fungi, such as yeast, where the cell divides into two, which almost or quite immediately become free from each other, each being a yeast plant. It can be noticed through all the families of the vegetable kingdom, though as we advance upwards in the scale the new body becomes more and more complex. We have the gemmæ of certain Algæ and Bryophytes, which are multicellular; we have in many Mosses branches which become detached by the dying off of the shoot behind them; in many Ferns buds are developed upon the pinnæ of some of their leaves, which when separated from the latter grow into complete ferns. In the Phanerogams we find this method illustrated by cuttings, which are pieces of the stem bearing buds; these, when detached and planted in suitable soil, put out adventitious roots from the base of the cutting, and develop into plants like the original one. Another instance is afforded by the buds which many leaves, notably those of *Bryophyllum*, put out when wounded. These also develop adventitious roots, and young plants arise which become independent. Other plants produce underground buds, tubers, &c., as already noticed. One of the chief features of vegetative reproduction is that the new plant represents the same phase of the life cycle as its parent did. The gemmæ of Mosses, which arise on the gametophyte, give rise to other gametophytes; the buds of the ferns, the cuttings or buds of the Phanerogams develop into new sporophytes like their parents. Alternation of generations is thus left altogether unaffected by vegetative reproduction.

Some curious cases of this vegetative method are known. In the embryo sac of *Cœlebogyne* there is no fertilisation of the oosphere, but still one or more embryos arise. This is caused by a vegetative budding of certain cells of the nucellus, which grow into the interior of the embryo sac and develop into embryos.

A further peculiarity of vegetative reproduction is that the new individual is developed continuously on its origination. There is no resting period, such as we find in most cases to mark the behaviour of the more specialised reproductive cells to be discussed below.

Besides vegetative reproduction we have two cases of the production of special cells to subserve this purpose. In the first of these, cells are differentiated which, after a longer or shorter period of quiescence, can grow out into new plants. These cells, possessing in themselves the power of producing new individuals, are known as *asexual* cells. They are differently named according to the phase of the plant on which they originate; those borne upon the sporophyte being called *spores*, those on gametophytes *gonidia*. There is, however, no further difference between them; indeed, by many writers the name *spore* is applied to both.

The fact that they do not usually germinate till after a period of rest, though this is often not very prolonged, suggests that they originated in a need for the plant to develop certain cells which should possess the power of passing through times of unfavourable conditions without destruction. Such unfavourable conditions would be likely to kill the more delicate vegetative reproductive bodies. This view is supported by the fact that many of the lower plants, particularly *Yeast*, do not produce gonidia when conditions are suitable for the life of the ordinary individual, but can be made to do so by cultivating them under adverse conditions of moisture, food supply, &c.

The gonidia which occur upon the gametophytes of the Algæ and Fungi are produced in various ways; they may occur singly or in large or small numbers in the interior of particular cells known as gonidangia; they may be produced by abstriction from a cellular outgrowth of the thallus; in this case again the number produced from a single cell may vary within wide limits. The various names given to them, such as *ascogonidia*, *stylogonidia*, *teleutogonidia*, indicate various conditions of this kind, and not any difference in their own structure. As a rule, they are small spherical or flattened bodies, clothed with a cell-wall; in both Algæ and Fungi cases occur where they have no such coating and are able to swim about by means of cilia. These forms are called *zoospores*, or *zoogonidia*.

In the higher plants, in which they originate only on the sporophyte, though possessing fundamentally the same structure as in the lower ones, their walls show more differentiation, possessing two coats, and often having the outer one curiously sculptured or furnished with projecting ridges or spines. Some have a third coat derived from the disintegrated mother cells and tapetum.

In some Pteridophyta an important variation makes its appearance; the spores are no longer all alike, but two kinds are produced, the microspores and the megaspores. This phenomenon is known as *heterospory*, and it extends also throughout the next group, the Phanerogams.

The microspores have the structure already described; the megaspores in the Pteridophyta are much like the microspores, except in size; in the Phanerogams they are simpler, having, with the exception of those of the Cycads, a single wall which remains thin and delicate. In this group too the megaspore is never set free from the sporangium, nor is the latter detached from the plant until after the germination of its spore.

The body produced from the germinating spore or gonidium is always a gametophyte, though often it only produces other gonidia.

In the second case in which there is a production of special reproductive cells, these are incapable alone of producing a new individual, but must fuse together in pairs to bring about this result. They are consequently called *sexual* cells or gametes. These probably took their origin from the asexual form. The phase of the plant on which they occur is always the gametophyte. The latter can consequently give rise to either sexual or asexual cells or both, while the sporophyte can only produce the latter.

In all the higher plants the gametophyte and sporophyte regularly alternate with each other, each producing the other phase of the life cycle. This phenomenon is known as *antithetical* alternation of generations. In the lower forms it is not at all regular in its occurrence; the sporophyte being altogether unrepresented in some, and only occurring at intervals in others.

We get in some of the former a succession of gametophytes, which reproduce themselves many times in succession by gonidia and do not develop sexual cells at all. After a number of generations have been thus produced asexually, a form arises which bears gametes, and these after fusion produce again a gametophyte which only develops gonidia. The gametophyte which does not develop its gametes is called a *potential* one, in contradistinction to one which does, and which is known as an *actual* gametophyte. The alternation of actual and potential gametophytes, where the resulting plant is in all cases similar to its parent, is called *homologous* alternation in contradistinction to antithetical, explained above. In such an alternation there is usually an absence of regularity, many potential gametophytes being developed in succession before an actual one arises.

The latter fact appears to indicate that in most plants continuous reproduction by asexual cells is attended with some deterioration of the plant's constitution, which becomes again invigorated by the occurrence of the sexual mode.

The phenomenon of heterospory involves the production of two gametophytes to one sporophyte, as each of the former produces its appropriate prothallus. Such plants show in their life cycle, therefore, three forms, one sporophyte, and two gametophytes, the latter occurring synchronously.

It is noticeable, further, that as we pass through the several divisions of the vegetable kingdom the predominant form of the plant changes. In the Thallophyta it is always the gametophyte; the sporophyte is not universal there, and is never more than a small structure, which nearly always remains attached to the gametophyte. In the Bryophyta the two phases are more nearly alike in degree of development; the gametophyte is always the vegetative body, while the sporophyte often shows the greater histological differentiation. It is always parasitic upon the gametophyte, and never attains a higher degree of morphological value than a thallus. In the Pteridophyta the sporophyte is the predominant form, and takes on the vegetative functions. The gametophyte shows continuous retrogression, and in the highest members of the group is almost entirely enclosed in the spore. In the Phanerogams the reduction in size is still more marked; in the Angiosperms the female gametophyte consists of only a few cells developed in the interior of the spore, while the male one is a tubular outgrowth from the pollen grain.

The gametophyte was doubtless the primitive form of the plant. The gradual appearance of the sporophyte can be observed still in the group of the Algæ. In Œdogonium the fertilised cell does not grow out into a new filament, but produces in its interior four zoospores which escape from it, and after a period of rest germinate and produce new plants. The fertilised cell here represents the sporophyte, which is reduced to a single sporangium. In Coleochæte the zygote is invested with a covering derived from the adjacent cells, and after sinking to the bottom of the water it germinates, producing inside its coating a small mass of cells, each one of which liberates a zoospore. There is here a sporophyte of a slightly higher type than that of Œdogonium. Somewhat more complex sporophytes occur among the Rhodophyceæ. An indication of the sporophyte may perhaps be seen in Spirogyra, where the nucleus of the fertilised cell divides into four, though no definite cells are formed. On germination of the zygote, however, only one filament grows out.

It was suggested above that probably the sexual cells were originally derived from asexual ones. A study of such forms as *Hæmatococcus* and *Ulothrix* leads us to this view. In the former two forms of zoogonidia are produced, which differ from each other only in size. In Ulothrix the same thing is seen, but there is a difference in their behaviour. The larger ones are asexual, but the smaller generally conjugate or fuse in pairs They represent, therefore, the sexual cells or gametes. This is the more likely, as the cells which fuse are generally, if not always, produced by different plants. The sexuality is not, however, well pronounced, for if one does not become fused with another, it can still germinate independently.

The gradual differentiation of the gametes into definite male and female individuals has already been traced in the section on the Thallophyta. When completely differentiated the male cell, which is known as an antherozoid, is a small free-swimming body, furnished with cilia. This form, which is the most perfect known, is not, however, of universal occurrence. In the Fungi the male gamete is almost always an undifferentiated mass of protoplasm which sometimes becomes free from the cell in which it is produced, but is then clothed with a cell-wall and has no power of locomotion. Sometimes it is not set free until it actually passes into the oogonium. In the Rhodophyceæ it is similarly unciliated, though at first it is a naked cell. The same want of differentiation is seen in all the Phanerogams, where the male gamete is represented by a portion of the protoplasm of the pollen tube.

The female gamete is more uniform, being generally a larger mass of protoplasm, with no cell-wall, and in all but the lowest forms incapable of motion. Below the Chlorophyceæ it is always set free and is fertilised in the water; in some forms of that group and in all above it it remains in the cell in which it is produced, an oogonium or an archegonium as the case may be. In the Angiosperms it is not even developed in an archegonium. A curious peculiarity is noticeable in the Rhodophyceæ, where the female organ, known as a procarp, contains no differentiated female cell. In the Ascomycetous fungi the same absence of differentiation is seen, though possibly there is no sexuality.

The peculiarity of sexual reproduction is that the gametes are incapable of giving rise to a new individual without fusion of a male and female together. In this process nucleus unites with nucleus and protoplasm with protoplasm. In the fusion of the nuclei in the Phanerogams, however, the chromosomes do not unite, so that the nucleus of the zygote or fertilised cell has twice the number of these that that of each gamete possessed. When the zygote germinates, the first nuclear division is so carried out that each daughter-nucleus receives half the chromosomes from each sexual nucleus.

The cells which fuse may be alike, or may be dissimilar; in the former case the process is spoken of as *conjugation*, in the latter case *fertilisation*. The resulting body is called the zygospore or the oospore respectively; the term 'zygote' is now generally used instead of either of these. Conjugation only occurs among the comparatively undifferentiated Thallophyta.

The mode of bringing the gametes together varies with the habit of life of the plants. Where the antherozoid is motile it makes its way to the oosphere by means of its cilia, which enable it to swim freely in water. In those forms with a terrestrial habit, such as the Bryophyta and Pteridophyta, in which the antherozoid is ciliated, fertilisation can only be brought about when the gametophytes are moistened, as is the case from time to time. The antherozoids are attracted to the archegonia by some constituent of the mucilaginous matter which is excreted from their necks when they open. In the Mosses this has been ascertained to be cane sugar; in the Ferns it is malic acid or one of its salts. In the Rhodophyceæ and such Ascomycetes as possess sexual reproduction the passive male gamete, known as a spermatium, is floated to the female organ or its trichogyne by currents in the water.

In the Phanerogams, where the female gametophyte is always attached to the parent sporophyte, such a means of fertilisation is of course impossible. For fertilisation to occur it is necessary that the two gametophytes shall be produced in close propinquity to each other. This is effected by the bringing together of the two spores concerned in developing them. The microspore or pollen grain is carried by various means to the neighbourhood of the megaspore; in the Gymnosperms it falls upon the megasporangium itself; in the Angiosperms upon the stigma of the pistil in which the megasporangia are hidden. As it germinates, its gametophyte, the pollen tube, makes its way through the intervening tissues till it reaches the megaspore itself, close to the archegonium in the first case, and to the oosphere when there is no archegonium. Fusion of the gametes produced in each gametophyte then becomes possible, and by a deliquescence of the separating walls they come into contact with each other and their union takes place.

In these higher plants we have two processes necessary for sexual reproduction, the one the approximation of the spores, or *pollination*, the other the fusion of the gametes, or *fertilisation*. Frequently the latter term is loosely and erroneously applied to the former process, as when the *fertilisation of flowers* is spoken of. The process is one of pollination, and may be followed by fertilisation or not according to circumstances.

When the cells which fuse are derived from the same gametophyte, the term *self-fertilisation* is applied to the process; when they come from different ones it is called cross-fertilisation. Self-fertilisation in the strict sense is extremely rare; even in the Thallophytes the uniting cells usually originate on different plants. The term 'self-fertilisation' has been used very generally to indicate the pollination of a pistil by pollen from the same flower; it is however better to speak of this as *self-pollination*. Speaking strictly, self-fertilisation cannot take place in heterosporous plants, as each spore produces its appropriate gametophyte and the two sexual cells never arise upon the same one. Cross-fertilisation has been found always to result in stronger and healthier plants than self-fertilisation. Cross-pollination, or the bringing together of spores from different flowers, or from different plants, of the same species, also yields more and better seeds than self-pollination.

Very many mechanisms have been developed in different plants to secure this end. Pollen may be carried from flower to flower by wind or water, or by the agency of insects or other animals. From this point of view plants have been classed as *anemophilous* or wind-pollinated, *hydrophilous* or water-pollinated. *entomophilous* or insect-pollinated, or *zoophilous* or those pollinated by other animals.

Of these methods of pollination the anemophilous and the entomophilous are the most widespread. In the former case certain structural features are associated with the mode of transference of the pollen. It is produced in such flowers in great abundance, is extremely light and dry, and in some cases furnished with bladders to aid its transport. The receptive organ is sometimes a bulky cone, the leaves of which are separated from each other and from the common axis by spaces into which the pollen may drop; sometimes it is a much divided or plumose stigma, often furnished with hairs, so that pollen falling on it may be readily retained. The method is a wasteful one and involves the production of a superabundance of pollen. On the other hand anemophilous flowers are always inconspicuous and of a comparatively humble type.

Flowers which are pollinated by insects are usually much larger and more showy, not infrequently possessing irregular corollas, and are often very highly coloured and provided with characteristic odours. Their perianths and sometimes their sporophylls are highly modified to adapt them to the habits of their insect visitors. As a further attraction to the latter they usually produce honey in some part of the flower, in such a situation as will lead to the removal of pollen by the insect in its search for the attractive liquid. The pollen itself also is often the object of the insect's visit. Many special mechanisms to secure the removal of the pollen from the microsporophyll and its deposition upon the stigma of another flower are to be met with; indeed, almost every Natural Order shows some modification in this direction. The consideration of them in detail, however, is beyond our present purpose.

Something akin to cross-pollination occurs in *Azolla* as already described; the massulæ or collections of microspores being floated to the macrospores, to the floats of which the glochidia attach them.

These mechanical adaptations are, however, not the only means we find to secure cross-pollination. There are peculiarities connected with what we may call the receptivity of the pistil for any particular pollen. Of these the most generally occurring is *dichogamy*, or the maturing of the microsporophylls and the megasporophylls at different times. Two varieties of this condition are met with; in the first, known as *protandry*, the stamens with their pollen are mature while the stigma is still too little developed to be pollinated. Examples may be found in the Gentianaceæ, Onagraceæ, Campanulaceæ, Compositæ, &c. In Parnassia the receptive surface of the stigma is not even formed until the anthers have discharged their pollen. The second condition is called *proterogyny*, and is the converse of the first, the stigma withering before the pollen is mature. This condition occurs in both anemophilous and entomophilous flowers; certain of the plantains (*Plantago*) and some grasses (*Anthoxanthum*, &c.) show it in the former group, as does *Scrophularia* among the latter.

Something corresponding to dichogamy is found among the Ferns, where the antheridia and archegonia on a prothallium do not mature simultaneously. Cross-fertilisation must consequently be the only form possible. The same peculiarity may be observed among the Mosses.

Another means often observed to secure cross-pollination is *diclinism*, or the production of the stamens and carpels in different flowers. Diclinous plants may be *monœcious* where the staminate and pistillate flowers are on the same plant, *diœcious* where they are on different plants, or *polygamous* where a plant bears hermaphrodite flowers as well as either staminate or pistillate ones.

The same terms 'monœcious' and 'diœcious' are often applied to the Cryptogams, when their sexual organs are upon the same or different plants. They then refer, of course, to the gametophyte and not the sporophyte phase as in the cases just quoted.

Some flowers show a peculiarity in form, which is sometimes an adaptation favouring cross-pollination. The plants possess flowers of two kinds, which are specially related to each other. The most familiar instance in our own flora is the common Primrose, which has five stamens and a club-shaped stigma. In some flowers the stigma is placed just in the throat of the corolla and the stamens some little way down its tube. In the remaining flowers the positions are reversed. We have here an adaptation to the visiting insect, for when it touches the stamens of a short-styled form it covers with pollen the part which will come in contact with the stigma of the next long-styled flower it alights upon. The best seeds are produced when each stigma is supplied with pollen from stamens occupying a corresponding position.

This arrangement is generally spoken of as *dimorphism*, of which, however, it is only one form. *Lythrum Salicaria* is trimorphic, having two sets of stamens of different lengths and a style which differs from both. There are three modes of arrangement of these organs, and, as in the Primrose, the most serviceable pollination is that which takes place when pollen from a stamen of a certain length is applied to a stigma of the same length.

Other arrangements are physiological rather than structural. Of these the strangest is what is called *prepotency*. When a stigma of a flower exhibiting this property is pollinated by pollen from its own stamens and at the same time by pollen taken from another flower, the latter is always the originator of the gamete by which fertilisation is effected. Some flowers show *self-sterility*, that is, they are never fertilised if only pollinated by pollen from their own stamens; in some few cases their own pollen acts as a poison to them.

Though cross-pollination is thus seen to be most advantageous, it is not universal. Self-pollination occurs in many plants; indeed, in some, special means have been developed to secure it in case cross-pollination fails to be effected. Only one of these need here be alluded to; this is *cleistogamy*, or the production of special flowers which do not open, in addition to the normal ones. The pollen grains put out their pollen tubes in the unopened flowers, sometimes not even escaping from the sporangia. The tubes grow towards the stigmas, and, penetrating them, reach the ovules as in the case of the normal flower, fertilisation resulting in the same way.

Though cross-fertilisation is seen to be most advantageous, it is only possible within certain limits. For a new individual to be produced, the sexual cells taking part in the process must have a certain degree of relationship; thus the antherozoid of a moss cannot fertilise the oosphere of a fern. The most favourable degree of relationship is that the two gametes shall be produced by different plants of the same species. Such a union results in greater numbers and greater vigour in the offspring. Plants, however, not so closely related, may produce offspring; thus we may have the union of gametes of plants standing to each other in the relation of varieties of the same species, or very frequently of distinct species belonging to the same genus, or even of species of different genera. Such fertilisation is known as *hybridisation*.

Hybrids generally exhibit peculiarities of form and structure intermediate between those of their parents; they are generally fertile with either of the parent species, but not usually so with another hybrid, or to a much less extent. When crossed with one of the parent forms the offspring tend to revert to that form.

The result both of pollination and of fertilisation is generally to stimulate the parts concerned to increased growth. In some Orchids the ovules are not formed in the ovary until the stigma is pollinated, and seem to arise in consequence of that process. The stimulus of fertilisation is still more marked. In the Mosses its result is to cause not only development of the sporophyte from the oosphere but a considerable additional growth of the archegonium, forming the calyptra. The same thing may be noted in those Rhodophyceæ where a bulky cystocarp is produced. The stimulus is, however, most easily observed in the Angiosperms, where not only is the oosphere excited to growth, forming the embryo, but the definitive nucleus of the embryo sac gives rise to the endosperm, and the pistil or collection of macrosporophylls and sometimes other parts of the flower undergo remarkable development, forming the fruit.

We have noticed that the asexual reproductive cell, whether spore or gonidium, is generally found to remain in a state of quiescence for some time after its formation. The same thing is seen in the case of the zygote. In the Thallophytes this resting period is sometimes a long one; in the higher Cryptogams it is not so noticeable, and in the Phanerogams, where the zygote is always developed inside the sporangium, it usually proceeds to active growth at once. In the latter plants, however, a resting period takes place later, after the seed is fully formed. The development of the young sporophyte in fact takes place in two stages, the one ending with what may be called the maturity of the seed, the other beginning with the process of germination. Seeds when detached from the parent plant preserve their vitality for a variable length of time, sometimes even for years, and are capable of germinating freely when exposed to favourable conditions.

The germination of the dicotyledonous seed occurs in one of two methods. In the first of these the cotyledons are thick and fleshy and remain under ground. As the seed absorbs water and swells, the radicle makes its way out through the micropyle, the testa bursts, and the plumule makes its way upwards, the epicotyl, or part between the cotyledons and the first leaves, circumnutating and emerging in the form of an arch, owing to the greater growth of one side. After reaching the air the region of greatest growth changes to the opposite side and the epicotyl straightens itself. During this time it subsists upon the nourishment stored in the cotyledons. This is called *hypogean* germination. In the other method, that of the so-called *epigean* germination, the cotyledons rise above the ground and become green, the hypocotyl behaving as did the epicotyl in the first case. These are generally, though not always, albuminous seeds, and the nutritive matter is stored outside the embryo. In both cases the root makes its way into the soil by virtue of its geotropism and apheliotropism, aided by the movement of circumnutation, and by the adhesion of the root-hairs to particles of the soil. In Monocotyledons the upper part of the single cotyledon generally remains in the seed and absorbs the nutriment from the endosperm, while its base elongates and thrusts the young plant downwards.

Sometimes the usual alternation of sexual and asexual reproduction in the higher plants is interfered with by the substitution of the vegetative method for one of them. In the phenomenon of *apospory* noticeable in some Ferns we have small prothallia developed on the back of the leaves in the place of spores. This is a case of the production of a bud instead of an asexual cell. Conversely, among the same group of plants, the sporophyte sometimes arises as a bud or vegetative outgrowth upon the prothallium, a phenomenon known as *apogamy*.

There is another kind of apogamy known which is generally termed *parthenogenesis*. This occurs among the Fungi, where, as in *Saprolegnia*, oospheres are formed in oogonia, which do not become fertilised and yet have the power of growing out into new plants. The formation of *azygospores*, described as occurring in *Mucor* and other plants, is another case of the same phenomenon. This parthenogenesis differs from the phenomenon described as occurring in *Cœlebogyne*, where nevertheless an embryo is produced without pollination. This we have seen to be due to a vegetative budding of the cells of the nucellus of the ovule, the buds growing into the megaspore and there developing into embryos.

GLOSSARY AND GENERAL INDEX

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— of gases, 412

— — nitrogen by Leguminosæ, 412; by pitcher plants, 414, 428

Accrescent. A term applied to the calyx, when it continues to grow after pollination of the pistil

Achlamydeous. Having neither calyx nor corolla

Acropetal succession. The regular development of leaves or branches in such order that the youngest is always nearest to the apex of the axis which bears them

Actinomorphic flowers. Flowers which can be divided into two precisely similar halves by every possible vertical section

Acyclic flowers. Those in which the leaves of the flower are arranged spirally on the axis instead of being in whorls

Adhesion. The condition of union to, or freedom from, one another of the separate whorls of the floral leaves

Adventitious. Arising irregularly, or not in acropetal succession. Applied to certain branches of stem or root

Æcidiogonidia, 98

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Æstivation. The mode in which the leaves of the perianth are arranged in the flower-bud

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Alternation of generations (antithetical). A regular alternation of gametophyte and sporophyte in the life cycle of a plant, 490

— — — *(homologous).* An irregular succession of gametophytes, some of which produce sexual cells while the remainder only develop gonidia, 10, 491

Amentaceous. Having its flowers arranged in catkins

Amido-acids, 418

Amœboid movements. The creeping movements of masses of naked protoplasm, 77, 86

Amphigastria, 121

Amphitropous. Semi-anatropous

Anabolism, 408

Anatropous ovule. One whose nucellus remains straight but which becomes inverted during development, owing to the greater growth of one side

Andrœcium. The collection of stamens in a flower

Androgonidium, 70

Androphore. The column or tube formed by the coalescence of the filaments of the stamens when the latter are monadelphous

Anemophilous, 495

Annulus, 128, 144, 160

Antheridial cell in Gymnosperms, 185

Antheridiophore. Any special part of the gametophyte on which antheridia arise

Antheridium. The organ in which the male gametes, usually antherozoids, are developed

Antherozoids or spermatozoids. Male ciliated gametes, with no cell-wall

Anthesis. The period at which the flower-bud opens

Anticlinal. A term applied to those cell-walls which are formed at right angles to the surface of the growing point

Antipodal cells, 196

Antitropous. Inverted. A term applied to the embryo

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Apocarpous. A term applied to the pistil when its constituent carpels are not coherent together

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Apogeotropism, 470

Apophysis, 129

Apospory, 130, 136, 499

Apostrophe, 463

Apothecium, 94

Aquatic phanerogams, 154

Archegoniophore. Any special part of the gametophyte on which archegonia arise
Archesporium. The cell or cells which by division give rise to the mother cells of the spores
Archicarp, 79, 91
Aril. A third integument which grows completely or partially over the seed springing from its base
Ascending sap, 390
Ascidia. The pitchers of such plants as Sarracenia, Nepenthes, &c.
Ascocarp, 93
Ascogonium, 93
Ascospores, 92
Ascus, 91
Asexual reproduction, 189
Ash of plants, 410
Astely = schizostely
Asymmetrical flowers. Those which cannot be divided into similar halves by any vertical section
Autœcious, 99
Auxiliary cells, 60
Auxospores, 50
Axil. The angle formed by the junction of leaf and stem
Azygospores, 64, 87

Basidia, 100
Basidiospores or basidiogonidia, 102
Bicollateral bundles. Those which have a strand of bast both before and behind the strand of wood
Bye-products of metabolism, 436, 439

Caducous sepals. Those which become detached from the flower when the flower-bud opens
Callus. The material which is developed upon the surface of sieve-plates. Also applied to the tissue which grows over and covers wounds made in a stem or root
Calyptra, 127
Campylotropous ovule. One whose nucellus is curved so that the micropyle is placed close to the hilum
Capillitium, 86
Capitulum (of Chara), 72
Carpogonium, 46, 59, 91
Carpophore. The part of the axis of the flower which is between or above the carpels, and to which they are attached
Carposporangia, 60
Caruncles = strophioles
Catabolism, 408, 435
Caudicles. The stalks of the pollinia in the Orchidaceæ
Cell-wall, composition of, 395
Chalaza. The point at which the vascular bundle reaches the ovule
Chemotaxis, 476
Chlamydospore, 87
Chlorophyll, 415, 437
Chloroplasts. The chlorophyll corpuscles, 408, 415
Chlorotic plants, 438
Chorisis. An increase in the number of the parts of a floral whorl due to the division or splitting of its primary members
Chromatophores = chromoplasts
Chromoplasts. Small protoplasmic bodies found in certain cells and containing colours other than green
Cilia. Vibratile filaments of protoplasm found on zoospores, gametes, &c. Also applied to the inner row of teeth of the peristome of mosses
Ciliary motion, 483
Circumnutation, 451
Cirrhus. A tendril
Cladode. A branch which in shape resembles a leaf
Cleistogamy, 497
Cleistothecium, 93
Cœnobium, 44
Cœnocyte. A plant body in which the constituent protoplasts are not separated from each other by cell-walls. Usually a common cell-wall invests the whole
Cohesion. The condition of union or freedom of the separate members of the whorls of the floral leaves
Cohorts, 5
Collenchyma. A parenchymatous or prosenchymatous tissue, the cells of which are thickened at their angles
Columella, 86, 128
Comose. A term applied to seeds which bear a tuft of hairs
Conceptacles. Depressions in the surface of the thallus of certain Algæ in which the reproductive organs are borne, 52
Conjugation. The fusion of two similar gametes, 193
Coriaceous. Leathery—applied to leaves
Cormophyte. A plant which possesses stem and leaf
Corona. A cup-shaped body formed by the lateral union of scales borne upon the perianth leaves at the junction of claw and limb, as in the Daffodil
Cryptostomata, 54
Crystalloids, 425, 426
Cupule. The involucre of the female flower of the Oak, Hazel, &c.
Cushion. The central thick region of the prothallus of the fern, 146, 147
Cystocarp, 41, 60
Cytase, 430, 432

Deduplication. A doubling of the number of parts of a floral whorl
Definitive nucleus, 196
Diageotropism, 470
Diaheliotropism, 469

Dialystely. A variety of polystely in which the separate steles remain for the most part independent during their longitudinal course
Diaphragm of Salvinia, 158
— Selaginella, 173
Diarch. A term applied to the stele of a root which has only two protoxylem groups
Diastase, 430
Dichogamy, 495
Dichotomous branching. Branching which results from the division of a growing point with two equal parts
— — in Liverworts, 115
— — in Selaginella, 170
Diclinism, 496
Diclinous. A term applied to plants whose flowers contain either stamens or pistil, but not both
Didynamous. A term applied to an andrœcium which consists of two pairs of stamens, one pair being shorter than the other
Differentiation, histological. The development of various kinds of cells in the interior of a plant
— *morphological.* The segregation of the plant body into different members
— *physiological.* The assignment of different functions to different structures, or different parts of a plant
Dimorphism, 497
Diœcious. Producing the male and female gametes on different plants. Also applied to Phanerogams in which staminate and pistillate flowers are produced on different plants, 496
Diplostemonous. A term used to indicate that an andrœcium consists of two whorls of stamens in regular alternation with the perianth leaves
Dissepiments. The partitions which are found in some compound ovaries
Distribution of seaweeds, 43, 57
Dorsiventral leaves. Those whose upper and lower halves have a different structure
Dwarf-male of Œdogonium, 70

Ectoplasm. The outer layer of the protoplasm of a cell
Egg-apparatus, 196
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Elaters of Equisetum, 164
— — Hepaticæ, 112
Embryo of Cycadeæ, 187
Embryonic branches of Chara, 18, 74
Emergences. Outgrowths from a plant which consist of ground tissue, covered by epidermis
Emulsin, 130, 133
Endophytic. Living in cavities in other plants, 49
Endosperm of Angiosperms, 197
— Gymnosperms, 186
— Selaginella, 173
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Enzymes, 120, 429
Epiblema. The outermost layer of cells covering the root
Epicotyl. The part of a seedling which extends from the insertion of the cotyledons to that of the first foliage leaves
Epigynous. Springing apparently from the summit of the ovary. A term applied to corolla and stamens
Epinasty, 451
Epiphragm, 129
Epiphytes. Plants which grow attached to other plants, but do not derive nourishment from them parasitically, 457
Epiplasm, 94
Episperm. The outer coat of the seed
Epispore, 157, 164
Epistrophe, 463
Erythrophyll, 440
Erythrozym, 430
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Etiolin, 438, 461
Eusporangiate. Having sporangia which arise from more than one cell, 132
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Exceptions to typical characters in Discifloræ, 263, 317
Exceptions to typical characters in Gamopetalæ, 263, 381
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Exodermis. A peculiarly thickened layer of cells, lying generally immediately under the epiblema of the root

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Fertilisation. The fusion of two dissimilar gametes. The term is sometimes used to signify the application of the pollen of a flowering plant to the stigma or ovule. This should, however, be called *pollination*, 493
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— — proteids, 418
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Gametangium. The structure in which sexual cells are produced
Gametes. Sexual cells
Gametophore. Any special part of the gametophyte on which gametangia, antheridia, or archegonia are borne
Gametophyte. The phase of the plant which is marked by the power of production of sexual cells or gametes. It may be actual or potential, 10, 191

Gamodesmic. A term used to indicate that the several vascular bundles of a stele are fused together instead of being separated by conjunctive or ground tissue

Gamopetalous. Having the petals cohering laterally (similarly gamosepalous)

Gamostelic. The condition when the steles of a polystelic stem are arranged in a ring and more or less completely fused together laterally

Gemmæ. Vegetative reproductive structures found among the Thallophyta and Bryophyta, 47, 74, 114, 121, 127

Genera, 3

Genetic spiral. The line which may be drawn round a stem with alternate phyllotaxis, passing in regular succession through the bases of the leaves

Geotropism, 470

Gills (of Mushroom), 101

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Globule. The antheridium of Chara

Glochidia, 157

Glucase, 430, 431

Glucosides, 427, 433

Gonidangia. The structures in which gonidia are produced

Gonidia. The asexual reproductive cells produced upon gametophytes. They are sometimes also called spores

Gonidiophore, 80

Gonidiophylls. Leaves of the gametophyte which bear gonidangia

Gonimoblasts, 60

Growth, 446

— effect of light upon, 463

— grand period of, 449

Gynandrous. A term used to indicate that the filament or filaments of the andrœcium of a flower are united with the upper part of the pistil, forming a central column

Gynobasic style. One which springs from the base of the carpel instead of its apex

Gynœcium. The pistil, or collection of carpels in a flower

Gynophore. The part of the axis of the flower between the insertions of the stamens and ovary

Haptera. The organs of attachment of certain Algæ, 45

Haustoria. The outgrowths through which many parasites absorb nourishment from their host plants. They are generally of the nature of roots

Heliotropism, 469

Hemicyclic flowers. Those in which the perianth leaves are arranged in whorls and the sporophylls in spirals

Hermaphrodite. A term applied to flowers possessing both stamens and carpels, also to gametophytes producing reproductive cells of both sexes

Heterocysts, 48

Heterodromous. A term used to indicate that the genetic spiral of the leaves of a stem turns in a different direction from those of the branches

Heterœcious. A term applied to certain fungi, which in different phases of their life infest two different plants, 99

Heterogamous. Having differentiated male and female gametes

Heteromerous, 106

Heterospory. The peculiarity of producing macrospores and microspores, possessed by many of the Pteridophyta and all the Phanerogamia, 190

Homodromous. A term used to indicate that the genetic spiral of the leaves turns in the same direction in the stem and its branches

Homoiomerous, 106

Homosporous = isosporous. Possessing only one kind of spore

Homotropous. Erect. A term applied to the embryo

Hormogonia. Vegetative reproductive bodies of the Cyanophyceæ, 48

Humus, 390

Hybridisation, 197

Hydrophilous, 495

Hydrotropism, 475

Hymenial layer, 94, 102

Hyphæ. The thread-like cells or filaments of the fungi

Hypocotyl. That part of the axis of a seedling which lies between the base of the radicle and the insertion of the cotyledons

Hypoderma. The region immediately underlying the epidermis

Hypogynous. Springing from the axis of the flower below the ovary. Applied to petals and stamens

Hyponasty, 451

Hypophysis, 199

Hypsophyll. Bract

Indusium. The membrane covering a sorus or collection of sporangia, 143, 155

Integuments, 181

Inulase, 430, 431

Invertase, 430, 431

Involucre. A whorl or collection of bracts at the base of a flower or an inflorescence

Irritability, 459

Iso-bilateral. A term applied to leaves whose upper and lower halves have the same structure

Isogamous. Having gametes which are not differentiated into male and female

Isomerous flowers. Those which have the same number of parts in each of the floral whorls

Isosporous. A term applied to plants which have spores of only one kind

Isostemonous. Having the same number of stamens as of sepals and petals

Karyokinesis. The process of indirect division of the nucleus
Klinostat, 471

Latent period, 487
Leptosporangiate. A term applied to those plants whose sporangia arise each from a single epidermal cell, 132
Leucoplasts. The plastids which form starch grains in parts of plants not exposed to light, 424
Ligule of grasses, 228
— — Lycopodinæ, 170, 171
Localisation of sensitiveness, 473, 478
Loculicidal. Splitting down the dorsal sutures. Applied to the dehiscence of capsular fruits
Lodicules, 229
Lysigenous spaces. Such as are produced by the absorption or disintegration of cells

Macrospores = megaspores
Manubrium, 72
Marcescent. A term applied to the calyx or corolla when it withers after pollination but does not become detached
Massula, 157
Megasporangia-development in Phanerogams, 181
Megaspores. The larger spores borne by heterosporous plants
Meiostemonous. Having fewer stamens than petals
Merismatic. Capable of division. A term applied to groups or bands of cells which undergo continuous multiplication
Meristeles. The branches of the stele which enter the leaves
Meristem. A collection of cells which increases continuously by cell-division
Metabolism. The chemical changes associated with the life of protoplasm, 408
Micropyle. The aperture left at the apex of the ovule in consequence of the integuments not completely enclosing it
Microsporangia-development in Phanerogams, 179
Microspores. The smaller spores borne by heterosporous plants
Monadelphous. A term used to indicate that the stamens of a flower are united by the bases of their filaments
Monandrous. Having only one stamen
Monochlamydeous. Having only one whorl of perianth leaves
Monœcious. A term applied to those Phanerogams which produce staminate and pistillate flowers upon the same plant. Also used to indicate gametophytes which bear both antheridia and archegonia, 496
Monopodial. A term applied to such branch systems as have a main axis produced by the continuous activity of a single growing point
Monostely. The condition in which the centre of the axis of the plant is occupied by a single stele which is continuous with the plerome
Mycelium. The delicate network of thread-like cells or cœnocytes which form the body of a fungus
Myrosin, 130, 433

Natural Orders, 1
Nitrification, 112
Nucellus. The body of the ovule, 181
Nucleoplasm. The substance of which the nucleus is composed
Nutation, 451
Nyctitropic movements, 464

Obdiplostemonous. A term used to indicate an andrœcium, which consists of two whorls of stamens, those of the outer whorl being opposite to the petals
Occurrence of *Monochlamydeous* flowers in Polypetalæ and Gamopetalæ, 263
Ochreæ. The stipules of the Polygonaceæ
Oidium, 82
Ooblastema filament, 60
Oogamous. Producing gametes of two kinds, one male, the other female
Oogonium. The organ in which the female gametes of the Thallophytes are developed
Oosphere. The female gamete before fertilisation
Oospore. The body formed by the fertilisation of an oosphere. Often called a zygote
Operculum. The lid of the capsule of a moss, 128
Orthostichies. The vertical ranks of the leaves upon a stem
Orthotropous. A term applied to ovules which grow vertically from the placenta, so that the chalaza and the hilum are close together at the base, and the micropyle is at the opposite end or apex
Osmosis, 385
Ostioles, 52
Oxidase, 133

Paleæ. Scarious leaves which form the outer covering of the flowers of grasses; also scales which are found at the bases of the flowers in the capitula of certain Compositæ

Pappus. The hairy or feathery calyx of the flowers of the Compositæ and allied orders
Paraheliotropism, 462
Paraphyses. Hair-like outgrowths formed among the sexual organs or sporangia of Thallophytes, Bryophytes, and Ferns, 53
Parasites. Plants which live upon other plants or animals by absorbing nutritive materials from their tissues, 457
Paratonic action of light, 463
Parthenogenesis. The development of a new plant from a sexual cell without fertilisation, 499
Pectase, 430, 433
Peloria. A term applied to the condition when flowers which are normally irregular in form become regular
Pepsin, 430, 432
Periblem. The embryonic tissue which gives rise to the cortex of vascular plants
Pericambium. An old name for the pericycle of the root
Perichaetium, 117
Periclinal. A term applied to cell-walls which are formed parallel to the surface of the growing point
Pericycle. The circumferential layer of the stele
Peridium, 102
Perigynium, 118
Perinium, 157
Periodicity, 486
Peripherical. A term applied to the embryo when it more or less completely surrounds the endosperm in the seed
Periplasm, 88
Perisperm. The remains of the nucellus of the ovule when it is not all absorbed by the megaspore or embryo sac during the development of the latter, 188
Peristome, 128
Perithecium, 94
Phototaxis, 470
Phototonus, 460
Phragmata. Spurious dissepiments crossing the ovary horizontally, as in *Cassia*
Phycocyanine, 45
Phycoerythrine, 45
Phycophæine, 45
Phycoxanthine, 45
Phyllaries. The bracts forming the involucre of the Compositae and allied orders
Phyllotaxis. The arrangement of the leaves upon the stem
Pileus, 101
Placenta. The part of the sporophyte on which the sporangia arise
Plasmodium. The body of a Myxomycete, 77, 86
Plerome. The embryonic tissue which gives rise to the stele
Pollination, 494
Pollinia. The masses of pollen produced in the lobes of the anthers of the Orchidaceae and Asclepiadaceae
Pollinodium, 79, 88
Pollinoid, 59
Polygamous, 496
Polystely. The condition in which the vascular tissue of the axis is arranged in several steles, each containing more than one vascular bundle
Præfloration. The arrangement of the leaves in the flower-bud
Prefoliation. The arrangement of the foliage leaves in the bud
Prepotency, 497
Primordial cells. Cells with no cell-wall
Primordial utricle. The part of the protoplasm of a cell which lines the cell-wall
Procambium. The embryonic tissue that develops into the vascular bundles
Procarpium. The female organ of the Rhodophyceæ and the Ascomycetes
Pro-embryo of Chara, 74
Pro-mycelium, 75, 87
Protandry, 496
Proteids, classification of, 419
Proterogyny, 496
Prothallium, 135
Protobasidium, 98
Protonema. The body produced from the spore of a Bryophyte, on which the gametophyte is developed vegetatively
Protoplasts. The separate aggregations of protoplasm, each of which constitutes the living substance of a cell, 383
Pseudocarp. A fruit into the composition of which other parts than the pistil enter
Pseudopodia, 85, 483
Pycnidia, 81, 95
Pyrenoids, 46

Quincuncial. A term applied to the æstivation of such flowers as have five leaves in a whorl, arranged so that two are overlapped on both sides by their neighbours, two are not overlapped at all, and the fifth is overlapped on one side only

Races, 2
Ramenta, 139
Raphe. The part of the funiculus which is adherent to the side of an anatropous or amphitropous ovule
Receptacle. The dilated apex of a peduncle on which several flowers are borne, as in a capitulum. Sometimes applied to the axis of the flower within or above the calyx
Rectipetality, 453
Rejuvenescence. A process in which the protoplasm of a cell withdraws from the cell-wall, rounds itself off in the cavity, and secretes a new cell-wall for itself. It is one of the processes of the formation of new cells
Rennet, 430

Replum. The spurious longitudinal dissepiment of the siliqua and silicula. It is formed by an outgrowth from the two placentas, and not by the edges of the carpellary leaves, 275
Respiration, 440
— anaërobic, 445
Retinacula. Glandular bodies at the bases of the pollinia in some Orchids
Rhamnase, 430, 433
Rhizophores, 171
Rhythm, 485
  artificial, 487
Root-hairs, action of, 391
Root-parasitism, 414, 458
Root-pressure, 392, 400
Rostellum. A peculiar projection into the flower of some Orchids. It is formed by a modification of one of the stigmas

Saprophytes. Plants which grow on decaying organic matter, from which they derive their nourishment, 66
Sarcocarp. The fleshy middle layer of the drupe
Schizostely. A condition in which an axis has several steles, each of which is composed of only one vascular bundle, 151
Sclerotia, 82, 95
Scutiform leaf of Salvinia, 159
Secondary growth in thickness in Thallophytes, 40, 44, 45, 52, 55
— in Isoëtes, 133, 174, 175
— — Ophioglossaceæ, 133, 150
Secretion, 436
Seed, structure of, 188
Self-sterility, 497
Septicidal. Splitting down the ventral sutures. Applied to the dehiscence of capsular fruits
Septifragal. A term applied to the mode of dehiscence of capsules in which the pericarp becomes detached and leaves the seeds adhering to a central column formed by the axile placentas
Series, 5
Sexual reproduction, 190
Shields, 72
Sleep movements, 461
Soredia, 107
Sorus. A collection of sporangia
Species, 2
- derivation of names of, 7
Spermatium, 59, 79, 91
Spermatozoid = antherozoid
Spermogonium, 79, 91
Sphacelia, 95
Sporidium, 97
Sporophore. The part of the sporophyte which bears the sporophylls. Usually applied to the inflorescence of Phanerogams
Sporophylls. Leaves which bear sporangia
Sporophyte. The phase of the plant which is characterised by the production of spores, and cannot produce sexual cells
Sports, 2
Starch grains, formation of, 421
Stele. A strand of tissue in which are embedded one or more vascular bundles, and which is surrounded by an endodermis
Stereome. The supporting tissue of the plant. It includes the vascular bundles and the sclerenchyma and collenchyma
Sterigma, 79, 91
Stipes, 101
Stipules. Branches of the hypopodium or leaf-base
Stoma of Marchantia, 115
Stomata, action of, 408
Stomium. The cells of the annulus of the fern which rupture to allow of the escape of the spores, 144
Stromata, 95
Strophioles. Small protuberances growing from various regions of the testa of the seed. They are never developed before fertilisation
Stylogonidia, 80
Stylopodium. The epigynous disc found in the flowers of the Umbelliferæ
Sub-classes, 5
Suspensor, 134, 165, 187, 198
Symbiosis. A term employed to denote the living together of two plants to their mutual advantage. The best example is afforded by the Lichens. See also 120, 154
Synangium, 132, 152, 168
Syncarpous. Having the carpels cohering together to form a compound ovary
Synergidæ, 197
Syngenesious. A term applied to stamens whose anthers are united together, while their filaments are free
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Tapetum. A nutritive layer usually surrounding the sporogenous tissue of the archesporium
Teleutospore or teleutogonidium, 80, 97
Tendrils, 472
Tensions in plants, 452
Tetradynamous. A term applied to the arrangement of the stamens in the Cruciferæ
Tetraspores or tetragonidia. The asexual reproductive cells of the Rhodophyceæ
Thallose liverworts, 114
Thallus. A plant body showing no differentiation into stem, leaf, and root
Theca. The moss capsule, 127
Thermotonus, 460, 467
Thyloses. A tissue often found in the interior of vessels or tracheïds. It is formed by a cell of the adjacent tissue boring its way into the vessel through

a pit and then multiplying by cell-division
Trama, 101
Transfusion tissue. A tissue surrounding the vascular bundles in the meristeles of the leaves of the Coniferæ
Transpiration, 402
Trichogyne, 46, 59, 79, 91
Trypsin, 430, 432
Tüllen = thyloses
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— universale, 102
Vernation. The arrangement of the foliage leaves in the bud

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Xerophilous plants, 456

Zoocænocyte. A free-swimming cœnocyte, 67
Zooglœa, 84
Zoogonidia or zoospores. Asexual reproductive cells with cilia but no cell-wall
Zoophilous, 495
Zygomorphic flowers. Those which can be divided into two precisely similar halves by a vertical section in one plane only
Zygospore. The body produced by the coalescence of two similar gametes
Zygote. The body produced by the process of fertilisation or conjugation. It may be a zygospore or an oospore
Zymogen, 129

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